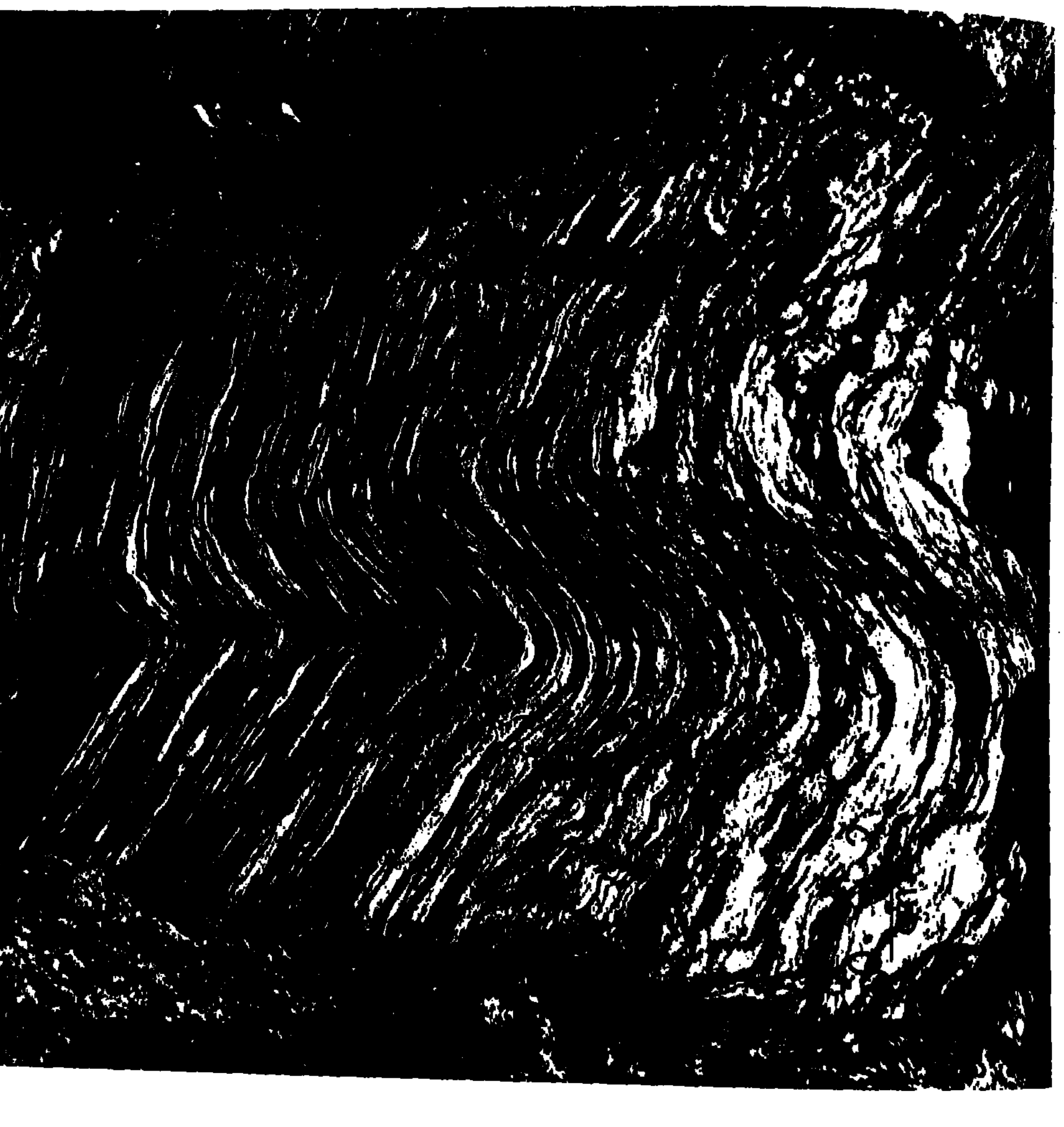
EOS Transactions, American Geophysical Union
Vol. 64 No. 8 February 22, 1983



EOS, Transactions, American Geophysical Union Vol. 64, No. 8, Pages 73–80 February 22, 1983

8170 Structure of the lithosphere
THERMAL PARAMETERS OF THE OCEANIC LITHOSPHERE ESTIMATED FROM GEOID HEIGHT DATA
A. Cazenave, B. Lago and K. Dominh (Groupe de Recherches de Géodésie Spatiale, Centre National d'Etudes Spatiales, 18, Avenue Edouard Belin, 31055 Toulouse Cédex - France)
Geoid height anomalies derived from SEASAT altimeter data have been analyzed across fracture zones and over ocean ridges in two limited regions of the South Pacific (Eltanin fracture zone system; East Pacific Rise) and Southeast Indian Ocean. Observed geoid height – age and geoid height derivative (with respect to age) – age relationships have been established. Comparison with theoretical relationships computed for the plate model of lithospheric cooling permits an estimation of the thermal parameters entering in the model. [illegible]
J. Geophys. Res., Red, Paper 3B1780

Volcanology

8499 Volcanology topics
OBSERVATIONS OF VOLCANIC TREMOR AT MT. ST. HELENS VOLCANO
M. Fehler (Geophysics Group; School of Oceanography, Oregon State University, Corvallis, Oregon, 97331)
Digital recordings of ground motion during tremor episodes accompanying eruptions at Mt. St. Helens Volcano in the state of Washington on August 7 and October 16–18, 1980 are studied. [illegible]

accompanying the cataclysmic May 18, 1980 eruption was at least one order of magnitude larger in amplitude than tremor during August and October. (Volcanoes, tremor, Mt. St. Helens, Seismology).
J. Geophys. Res., Red, Paper 3B0157

8699 Volcanology
RESUSPENSION OF VOLCANIC ASH FROM MT. ST. HELENS
P. V. Hobbs (Cloud and Aerosol Research Group, Atmospheric Sciences Dept., University of Washington, Seattle, 98195), D. A. Hegg and L. F. Radke
Measurements are presented of the size spectra of ash particles, previously deposited on the ground from the 18 May 1980 eruption of Mt. St. Helens, that were resuspended into the air in Eastern Washington. [illegible]
J. Geophys. Res., Green, Paper 2C1927

8699 Volcanology
MAGMA RESERVOIR SUBSIDENCE MECHANICS: THEORETICAL SUMMARY AND APPLICATION TO KILAUEA VOLCANO, HAWAII
M. P. Ryan (959 National Center, U. S. Geological Survey, Reston, Virginia 22092), J. Y. K. Blevins, A. T. Okamura and R. Y. Koyanagi
An analytic model has been developed for the prediction of the three-dimensional deformation field generated by the withdrawal of magma from a sill-like storage compartment, during an intrusion or eruption cycle. [illegible]
J. Geophys. Res., Red, Paper 3B0349

8499 Volcanology topics
EPISODIC RIFTING AND VOLCANISM AT KRAFLA IN NORTH ICELAND: GROWTH OF LARGE GROUND FISSURES ALONG THE PLATE BOUNDARY
Paul Bjornsson (Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964)
The rifting of the plate boundary in north Iceland ... [illegible]
J. Geophys. Res., Red, Paper 3B1660

General or Miscellaneous

9840 Techniques applicable in three or more fields (Error Detection and Correction)
AN OBJECTIVE PROCEDURE FOR DETECTING AND CORRECTING ERRORS IN GEOPHYSICAL DATA: 2. MULTIDIMENSIONAL APPLICATIONS
H. E. Fleming (National Oceanic and Atmospheric Administration, National Environmental Satellite Data and Information Service, Washington, D.C. 20233), W. L. Hill
[illegible]
J. Geophys. Res., Ocean, Paper 3C0347

News

Lasers: The Femtosecond Pulse

Laser applications in geophysics range from making hydrographic depth soundings to a myriad of types of spectrographic measurements on crystals and polycrystalline materials. Reducing the emitted pulse width is a recurring need in many scientific laser applications. In determinations of ocean bottom depth and of mean sea level by airborne laser systems, a pulse width of one nanosecond (10^{-9}) is barely sufficient to obtain the desired accuracy (± 30 cm). In crystal physics measurements, a pulse width of about one or two picoseconds (10^{-12} s) is required. An object of these specifications is to be able to operate at the time periods of ionic and molecular vibrations. It should be possible to study excitation and kinetic processes in a condensed material before they have relaxed or otherwise come to equilibrium.

According to a recent study at Bell Laboratories, researchers have now split the picosecond by producing an emitted-light pulse width of 30 femtoseconds (10^{-15} s, during which light travels a distance of about 0.3 µm) from a new colliding-pulse ring dye laser system (*Physics Today*, December 1982). This laser uses nonlinear optics to 'chirp' the pulse, a technique something conceptually similar to techniques employed in geophysical applications of radar delay-line pulse generators. That the production of a femtosecond pulse represents a 'real' state of the art is evidenced by the fact that such a pulse is too short to measure by conventional techniques. Techniques that in effect use the pulse to measure itself are necessary (*Ultrashort Light Pulses*, S. L. Shapiro, Ed., Springer-Verlag, New York, 1977).

The chirping method of compressing microwave pulses is done by superimposing a linear frequency sweep on the carrier frequency. The method for compressing picosecond optical pulses derives the same result, but the chirping process to produce a time-dependent shift of the carrier frequency is done optically. As achieved by the Bell Laboratories group the system employs a nonlinear optical fiber.

The process was first demonstrated a short time ago in nonlinear liquids. In these liquids the index of refraction changes in proportion to the intensity of light being transmitted. The nonlinear refractive index term results when the electric field produced by very intense light is of the same magnitude as the liquid's intramolecular field. Thus a light pulse consisting of an intense peak with leading and trailing edge tails is 'self' phase modulated,' as there is a time-dependent shift of the carrier frequency. When an optical pulse is coupled with several tens of meters of single mode optical fiber, the pulse can be compressed in time. In the radar-microwave analogy the optically chirped pulse is fed through an optical delay line consisting of a dispersive grating system that allows the high-frequency end of the pulse to arrive in time with the lower-frequency leading edge. This optical-fiber and grating delay line system was initially described by H. Nakatsuka, D. Grishkowsky, and A. C. Balant of the IBM Research Laboratory (*Phys. Rev. Lett.*, *47*, 910, 1981).

The mode-locked, dye-laser systems, including cavity dumping and autocorrelation techniques to measure the final pulse width, are now available commercially though they were unknown a decade ago. The colliding-pulse ring dye laser employed by Bell Laboratories is a new variant designed to enhance the mode-locking effect.

The new systems are an attempt to meet two basic requirements of laser applications. High-power pulse widths that are extremely narrow in time provide the necessary precision for airborne-laser tracking systems. They provide 'the most intense way we have of interacting with condensed matter without destroying it,' according to C. V. Shank of Bell Laboratories (*Phys. Today*, op. cit.). The state of the laser art now stands at a 30 femtosecond pulse that has peak power in the Gigawatt range.—*PMB*

XANES: Solid State Mineral Analysis

Researchers in the field of mineral physics have become aware of new analytical techniques for studying the electronic structure of solids; one such technique is the X ray absorption fine structure (XFAS) method. In this technique the fine structure of the X ray K-edge, for example, can be employed as a critical probe of the intricacies of a crystal structure (P. A. Lee, P. H. Citrin, P. Eisenberger, and B. M. Kincaid, *Rev. Mod. Phys.*, *53*, 799, 1981).

A similar, related technique, X ray absorption near-edge spectroscopy (XANES), is a relatively unknown method of studying the electronic structure of solids. XANES is new, and due to its complex nature, data on all but very simple solids have not yet been applied rigorously. Among the first XANES results on minerals is the recent study reported by G. Knapp, B. Veal, H. Pan, and T. Klipper (*Solid State Comm.* *44*, 1343, 1982) on perovskites, magnesiowustites, and other 3*d* oxides in the zircon and spinel groups. The interpretation of these results is still semiquantitative, being based on ground state and basic selection rule considerations. The results show, however, a strong correlation between near-edge spectra and crystal structure.

XANES, a lower energy version of EXAFS, is concentrated within 30 eV of a given X ray absorption edge; in some instances the two techniques coincide. As described by Knapp et al., '. . . XANES directly probes unoccupied states of the photoionized ion which occur at energies near the Fermi level E_F.' This study found that the near-edge spectral patterns of the phases containing 3*d* elements were essentially identical within a structure type, spinel, perovskite, rock salt, or zircon. The patterns were not dependent on the particular transition element even though the K-edge energies differed by several keV. Further, there was no dependence on differences in the occupied 3*d* electron populations (d^0 to d^8 were compared), but this result was consistent with dipole selection rules and was to be expected. The spectra are most sensitive to empty *p* states (above E_F), but the change in the number of *d* electrons for increase in atomic number would have little effect as well. The spectra are unusually consistent though, considering the range of composition and structure.

In certain spectra there is some indication of band complexities arising from transitions to a *p-d* mixed empty state. The case, *p-d* orbital mixing, results from a lack of a center of symmetry in tetrahedrally coordinated groups.

The results of the study by Knapp et al. indicate that the XANES technique can be used to deduce the valence states of cations. Their local site symmetry and coordination number can also be determined as characteristic.

These results are important, because application of this new technique may pave the way to determining the coordination of ions in complex mineral structures for the first time. Numerous cases exist in rather common minerals where the coordination with oxygen of cations remains unknown or poorly determined. The technique, like XFAS, requires a very large X ray flux. XANES studies may be among the first mineralogical studies to be done with synchotron radiation when facilities become available.—*PMB*

Awards Set For Study Abroad

Fulbright Program

Senior Scholar Fulbright awards for university teaching and postdoctoral research in 1984–85 are available in all academic fields for terms of 2–10 months in more than 100 countries. Applications and information may be obtained after April 15, 1983, on college and university campuses from the graduate dean, chief academic officer, or the international programs office. Interested persons also may write to the Council for International Exchange of Scholars, 11 Dupont Circle, Suite 300, Washington, DC 20036 (telephone: 202-833-4985). Please specify the country and field of interest.

Deadlines for submission of applications are June 15, 1983, for American Republics, Australia, and New Zealand, and September 15, 1983, for Africa, Asia, Europe, and the Middle East.

The Fulbright program is funded and administered by the U.S. Information Agency.

Research in India

The Indo-U.S. Subcommission on Education and Culture is offering 12 long-term (6 to 10 months) and 9 short-term (2 to 3 months) research awards for 1984–85. The fellowship program aims to open new channels of communication between U.S. and Indian academic and professional groups and to encourage a wider range of research activity between the two countries.

The fellowships, without restriction to field, include a stipend ranging from $1200 to $1500 per month, depending on academic and professional achievement and seniority; $350 per month is payable in dollars, with the balance paid in rupees. In addition, an allowance is awarded for study and travel in India and for international travel. Long-term fellows also receive an international travel allowance for dependents of $100–$250 per month, in rupees, for dependents; and a supplementary research allowance of up to 34,000 rupees.

For additional information and application forms contact the Council for International Exchange of Scholars, Attention: Indo-American Fellowship Program, 11 Dupont Circle, Suite 300, Washington, DC 20036 (telephone: 202-833-4985). The deadline for application submission is July 1, 1983.

The program is sponsored by the Indo-U.S. Subcommission on Education and Culture and funded by the U.S. International Communication Agency, the NSF, the Smithsonian Institution, and the Government of India.

Geophysical Events

This is a summary of *SEAN Bulletin*, *8*(1), January 3, 1983, a publication of the Smithsonian Institution. The complete Mt. St. Helens, Ol Doinyo Lengai, and Usu reports are included. The earthquake and meteorite fall reports are excerpts. The complete bulletin is available in the microfiche edition of *Eos* as a microfiche supplement or as a paper reprint. Subscriptions to the *SEAN Bulletin* are also available. For the microfiche, order document E83-002 at $2.50 from AGU Fulfillment, 2000 Florida Avenue, N.W., Washington, DC 20009. For reprints, order *SEAN Bulletin* (give dates and volume number) through AGU Separates; $3.50 for one copy of each issue number for those who do not have a deposit account; $2 for those who do; additional copies of each issue number are $1.00. For a subscription, order *SEAN Bulletin* from AGU Fulfillment. The price is $18.00 for 12 monthly issues mailed to a United States address; $28.00 (U.S.) if mailed elsewhere. Order must be prepaid.

Volcanic Events

Mt. St. Helens (Washington): New lobe extruded onto composite lava dome.
Kilauea (Hawaii): Major eruption in middle E Rift Zone may continue.
Long Valley (California): Seismicity declines; intense January swarm was accompanied by strains of 3–4 ppm and uplifts of up to 7 cm in epicentral area.
El Chichón (Mexico): Strong H_2S emissions but no new explosions; cloud data to 76°N; unusual sunrises and sunsets.
Pacaya (Guatemala): Minor flank lava emission.
Santiaguito (Guatemala): Occasional explosions; rockfalls.
Costa Rica: Temperature and gas data at Poás, Turrialba, and Irazú.
Ol Doinyo Lengai (Tanzania): Vapor and tephra cloud.
Langila (New Britain): Several vulcanian explosions per day.
Manam (Bismarck Sea): Little volcanic activity; steady, moderate seismicity.
Ulawun (New Britain): Weak vapor emission; seismicity increases.
Ruapehu (New Zealand): Summit inflation ends and crater lake temperature low; similar pattern observed before hydrothermal eruptions in 1980 and 1981.
White Island (New Zealand): Abrupt deflation.
Sakurajima (Japan): Increased explosive activity, ash ejection.
Usu (Japan): Decreased seismic activity; negligible ground deformation.

Mt. St. Helens Volcano, Cascade Range, S Washington, USA (46.20°N, 122.18°W). All times are local (GMT – 8 h). Increases in SO_2 emission, deformation, and seismicity preceded a series of small explosions and the extrusion of a new lobe onto the composite lava dome, the first since August 1982.

The rate of SO_2 emission, which had remained very low for several months, tripled between measurements on January 13 and 15 and remained between 60 and 110 tonnes/day through the end of the month. About 20 small, shallow earthquakes were recorded January 17–18, but seismicity declined and remained at background levels for the next 2 weeks. Heavy snow in the crater made deformation measurements impossible on the S and E sides of the dome, but very slow acceleration in the rate of outward movement of the dome's northern side began in mid-January. A few small gas and ash emissions occurred in late January.

Gas monitoring on January 30 showed that SO_2 emission had increased to roughly twice the rate of the previous 2 weeks, and SO_2 flux ranged from 170–260 tons/day through February 7. On January 31 a pronounced acceleration was measured in the outward movement of the northern side of the dome. Points on the western side of the dome, usually the area of most rapid outward movement, showed little such activity but sagged downward several tens of centimeters. A gradual, slight increase in the number of seismic events began February 1, but seismicity remained relatively weak, reaching about the level of the January 17–18 activity.

At 2339 on February 2 and 0256 the next morning, explosions sent plumes containing small amounts of ash to about 6 km altitude. A pilot reported that the cloud top was at 8 km altitude at 0015 on February 3. GOES East satellite images showed the plumes moving slowly toward the northwest. At 0430 a cloud about 150 km diameter remained centered over the volcano, but it had begun to diffuse 30 minutes later and by 0530 had reached nearly to Puget Sound, about 100 km from the volcano. Ashfall was reported at Olympia, near the S end of Puget Sound. During a predawn flight February 3, geologists observed that the explosions had created a small notch in the upper eastern flank of the dome. Within the crater the deposits from these explosions showed a complex stratigraphy. Rare breadcrust bombs were found at the top of the deposits. A laterally-directed component from one or both of the explosions melted snow on the crater's eastern floor and wall, producing a mudflow that reached Spirit Lake. The ash column from a third explosion on February 3 at 1728 reached about 4.5 km altitude. This explosion enlarged the eastern flank notch to 60–100 m deep and 80–100 m wide. Deformation data of February 3 and 5 showed continued acceleration of outward movement of the northern side of the dome, reaching 5–6 cm/day by February 5. Visual observations showed severe deformation of the eastern side of the dome, where a large wedge of rock just south of the notch had tipped up and out several meters. Locatable seismic events stopped February 5 and only events typically associated with steam emissions and rockfalls were detected during the next several days.

Late February 5 the USGS and the University of Washington issued an extended outlook advisory notice stating that an eruption was likely within the next week and could include some explosive activity. Poor weather prevented observations until about noon on February 7, when geologists observed the extrusion of a new lobe of lava from the floor of the eastern flank notch. It advanced mainly toward the east, filling the notch, and by afternoon had reached the top of the talus pile at the base of the dome. From the air, geologists estimated that the new lobe extended roughly 100 m E–W and 50 m N–S. A small explosion occurred from the dome at 1640 on February 7.

Weather conditions prevented access to the crater for the next few days, but seismographs recorded rockfall events, suggesting that the new lobe continued to advance. Glimpses of the dome beneath low weather clouds February 14 indicated that the new lobe was still growing.

Information contacts: Tom Casadevall, Chris Newhall, Donald Swanson, and Steven Brantley, USGS Cascades Volcano Observatory, 5400 MacArthur Blvd., Vancouver, WA 98661 USA; Steven Malone, Graduate Program in Geophysics, University of Washington, Seattle, WA 98195 USA; Dennis Haller, NOAA/NESDIS, Camp Springs, MD 20233 USA.

Ol Doinyo Lengai Volcano, N Tanzania (2.751°S, 35.902°E). All times are local (GMT + 3 h). On January 6 at first light (about 0600), Philip Sanders observed a cloud of vapor and fine tephra, not present the previous day, emerging from the volcano. During 12 hours of observation, the size of the plume gradually increased, but there were no audible explosions. Clouds obscured the summit the next morning and no additional observations are available. Ol Doinyo Lengai's last reported eruption was July–October 1967.

Information contact: John E. Sanders, Department of Geology, Barnard College, Columbia University, 606 W 120th St., New York, NY 10027 USA.

Usu Volcano, Hokkaido, Japan (42.53°N, 140.83°E). Seismicity and ground deformation at Usu ended in spring 1982, after 58 months of activity. The monthly number of recorded seismic events had gradually declined since the major eruption in 1977 (see *SEAN Bulletin*, *2* (8–9)), but remained above the background level through 1981, when approximately 308 seismic events were recorded per month (see *SEAN Bulletin*, *7* (3)). Ground deformation had also continued since the eruption. The rate of uplift of the cryptodome decreased from about 2 cm per day in 1980 to about 0.8 in 1981. Northward lateral movement of the northern flank also continued through 1981.

In 1982, seismic activity decreased to the background level of about 10 events per month by April: 496 events were recorded in January, 231 in February, 79 in March, 10 in April, and 11 in May. Ground deformation has been negligible since April 1982.

Information contact: Office of Volcanic Observation, Seismological Division, Japan Meteorological Agency, 1-3-4 Ote-machi, Chiyoda-ku, Tokyo 100, Japan.

News (cont. on p. 84)

The Oceanography Report

The Oceanography Report

The focal point for physical, chemical, geological, and biological oceanographers.

Associate Editor: Arnold L. Gordon, Lamont-Doherty Geological Observatory, Palisades, New York, 10964 (telephone 914/359-2900, ext. 325)

Greenland Sea Ice/Ocean Margin

Miles G. McPhee

Introduction

One of the fundamental obstacles to understanding both weather and long term climate variability of polar and subpolar regions lies in knowing what controls the position and behavior of the boundary between open and ice-covered ocean, the marginal ice zone (MIZ). Over the seasonal cycle, variation in sea ice coverage of the world ocean is about 25 million km^2, roughly 7% of the total area; thus a significant portion of the ocean is at some time during the year part of the MIZ.

From the point of view of air-sea interaction, the MIZ is a very complex system: an interface between ocean and atmosphere with potentially extreme horizontal and vertical temperature gradients and large variations in mechanical properties. The 'joker-in-the-deck' is, of course, sea ice—it modifies momentum transfer from the atmosphere; drastically alters surface albedo; serves as an efficient thermal insulator; damps surface wave motion; and, because it is relatively fresher than sea water, may substantially change both temperature and salinity structure in the upper ocean by melting or freezing. Sea ice is highly mobile in response to surface wind, capable of traveling tens of kilometers per day. It thus represents a negative source of both salt and heat that can be advected long distances across water–mass boundaries by atmospheric systems. It is estimated (e.g., *Hibler*, 1979) that fresh water exported from the Arctic Basin through Fram Strait as sea ice (about 10^5 m^3 s^{-1}) is roughly comparable to the total continental runoff entering the basin. In this sense, the MIZ of the North Atlantic, despite its limited area, is the terminus of a vast territorial watershed.

Over the past decade, field experiments (notably the Arctic Ice Dynamics Joint Experiment) and theoretical modeling of sea ice and the adjacent atmospheric and oceanic boundary layers have dramatically increased our understanding of the behavior of ice-covered oceans. At the same time, there has been much interest in open-ocean frontal and mixed layer processes. In 1979 a workshop on the Seasonal Sea Ice Zone, organized by Wilford Weeks, provided the first systematic, multidisciplinary approach to identifying problems faced in understanding seasonal sea ice and provided experimental techniques for addressing them (*Andersen et. al.*, 1980).

In subsequent meetings a research strategy was formulated from which emerged a structure known as MIZEX (Marginal Ice Zone Experiment). MIZEX is an international, interdisciplinary project aimed at studying specific processes in the MIZ as part of a more comprehensive effort to understand how the annual and long-term variability of polar ice margins relate to large-scale atmospheric and oceanic circulation (Untersteiner, N., Air-sea-ice interaction research program for the 1980s, unpublished report, Applied Physics Laboratory, University of Washington, Seattle, 1983). The primary focus of MIZEX is the Greenland Sea ice edge in the region north and west of Svalbard, where most of the exchange between the Arctic Ocean and the rest of the world ocean occurs. The general research strategy, described by *Wadhams et. al.* (1981), includes field experiments planned for the summers of 1983 and 1984 (MIZEX 83 and MIZEX 84) (*Johannessen, Hibler, et. al.*, in press) with follow-on winter and summer experiments later in the decade. Complementary work is planned for the ice edge in the Bering Sea (MIZEX WEST), as described in *Eos*, December 21, 1982, p. 1220.

Scientific Considerations

For conceptual and organizational clarity, the MIZEX effort has been broken into seven subgroups: remote sensing, meteorology, ice, oceanography, biology, acoustics, and modeling. Some of the major problems and proposed work in each discipline are described below; more complete descriptions may be found in *Wadhams et. al.* (1981); and *Johannessen, Hibler, et. al.* (in press).

Remote Sensing

Given the extent and inaccessibility of areas affected by the MIZ, remote sensing is the only practical way of applying increased understanding from experiments like MIZEX to long-term monitoring and routine prediction of ice-edge characteristics. Eddy-like structure along the ice edge in the Greenland Sea has been shown by LANDSAT image (see cover). Similar images have been attained with microwave sensors (e.g., *Johannessen, Johannessen, et. al.*, in press), demonstrating the feasibility of all-weather, all-season remote observation. If MIZEX succeeds, for example, in providing reasonable estimates of cross-edge heat and mass exchange in eddy or banding processes, then routine surveillance of such features will provide much improved estimates of large scale heat and mass budgets.

From an experimental standpoint, remote sensing provides the overall view necessary to identify special features for intensive study. Because persistent cloudiness is anticipated, microwave sensors (SAR, SLAR, and Passive) will be used extensively. Studies of ice deformation obtained by tracking identifiable natural and artificial targets will complement buoy and transponder measurements.

There will also be a concerted effort to measure and understand the effect of changing surface conditions in the MIZ on scattering and emission properties.

Meteorology

The lower boundary of the atmosphere across the MIZ changes from a maritime regime, with low albedo and moderate temperature, to a highly reflective and, during much of the year, very cold regime. These changes, combined with dramatic variation in surface roughness, can impose large gradients in radiative fluxes, in surface stress, and in turbulent moisture and heat fluxes. Over pack ice, the boundary layer is usually stably stratified, with low, strong inversions. If this cold air is advected over open water with a strong temperature contrast, turbulence is intensified. By the same token, warm air advected over the cold surface is stabilized, with decreasing turbulence levels. Ice is generally thought to be rougher than the ocean surface, so that for the same surface wind and stability, turbulent drag over pack ice is greater than over the open sea; furthermore, roughness of the ice itself is often increased within the MIZ by rafting and pulverization. Sorting out these various effects presents a considerable challenge but is important for understanding how the ice and underlying water respond to the wind.

The MIZEX experiments will employ a variety of meteorological instruments for surface layer studies, deployed from ships and ice floes, along with aircraft boundary-layer measurements, radiosonde launchings, acoustic sounders, closely spaced surface pressure arrays, and buoy-mounted weather stations. An active atmospheric modeling component will complement the field measurements.

Ice

Sea-ice studies in the MIZ divide roughly into two classes: one concerned primarily with the thermodynamic growth, decay, and internal structure of ice; the other concerned with the mechanical properties of sea ice as a material affected by dynamical forces, mainly wind and current.

Ice in the MIZ is broken into much finer individual floes and pieces than are found in the interior pack. Attenuation of surface wave energy by the pack ice is certainly a major factor in this break-up; gradients in other forces, such as horizontal current shear, may also contribute. These interstitial areas of open water not only change the mechanical properties of the ice, but also modify the radiation balance and the mean surface temperature sensed by the atmosphere. In summer, melt rates may be enhanced by increased insolation between floes; in winter, ice production is increased by continual opening and closing.

Water near the margin may contain more sensible heat than is usually found in the Arctic mixed layer, giving oceanic heat flux a greater role in the thermodynamic energy balance that controls ice thickness. The mass balance of ice regulates buoyancy flux into the oceanic boundary layer; thus, if oceanic sensible heat is available, the growth rate can serve as an important feedback parameter.

Kinematics of ice motion in the MIZ are also of much interest. Buoy and satellite imagery studies indicate comparatively large, shear normal to the ice edge and divergence along the East Greenland Drift Current. MIZEX will also study attenuation of inertial and tidal oscillatory motion.

Measurements planned include detailed studies of changes in mass, concentration, and floe size distribution, along with energy budget observations and properties of ice measured both in situ and cored for more extensive laboratory analysis. Radar positioning techniques and satellite navigation will be used to study kinematics of the ice drift field with an array of drifting buoys. In addition, mean motion, wave and collision accelerations, ablation, and other properties will be studied at the extreme ice edge, including eddies and bands.

Oceanography

Modification of the upper ocean across the ice edge is often extreme, with large changes in temperature and salinity, large horizontal gradients in vertical density structure (with corresponding geostrophic shear), and rapid variation in surface momentum and buoyancy flux. At times, the MIZ coincides with the surface manifestation of a permanent, oceanic front (e.g., the East Greenland Polar Front), which may in turn be tied to a topographic feature (the shelf break); but as is the case in many marginal seas and in most of the Southern Ocean, the ice edge itself often forms a rapidly migrating, oceanic frontal zone. These fronts exhibit a variety of interesting features: eddies (see cover figure and *Johannessen, Johannessen, et. al.*, in press), fine structure (*Paquette and Bourke*, 1981), jets, and meanders. A summertime Soviet project at the Chukchi Sea MIZ noted a jet, directed along the ice edge so that open water was on the right, that persisted for the duration of the experiment regardless of wind direction (*Nikolaev*, 1973). The jet, which meandered on scales of about 90 km, probably resulted from geostrophic adjustment between relatively warm and saline water from the south and a lens of water freshened by ice melt.

Ice-edge upwelling and other mesoscale circulations appear in the MIZ; they are thought to be driven by surface gradients in stress or buoyancy flux. The Chukchi ice-edge jet mentioned above seems to fall in the latter class, since it was apparently independent of local wind. On the other hand, *Buckley et. al.* (1979) observed a large upwelling event north of Svalbard in early winter (Fig. 1), which they attributed to a surface stress gradient much like coastal upwelling. In this case it is hypothesized that sea ice, because of its greater upper surface roughness, imparts more momentum to its underlying boundary layer, causing Ekman divergence at the ice edge.

Boundary layer and surface layer processes are also an active area of research. Rapid melting at the ice margin can yield in the upper ocean an input of fresh water at a rate comparable to that of a torrential rainfall, creating a stable boundary layer analogous to the nocturnal boundary layer of the atmosphere. *McPhee* (in press) offers the resulting reduction in drag on the ice underside as an explanation for divergence of bands of sea ice away from the main pack under off-ice winds. Absorption and reflection of surface gravity wave energy is also a significant factor in the MIZ, invoked to account for the relatively sharp ice edge often observed. Wave radiation stress has also been suggested as a primary factor in the formation of ice-edge bands (e.g., *Wadhams*, in press).

An ambitious oceanographic measurement program is planned for the MIZEX experiments, including current meter moorings, both bottom anchored and suspended from the surface; extensive hydrography from ship and helicopter; profiling current meter systems; boundary layer turbulence measurements; expendable temperature and velocity probes; high frequency acoustic soundings, and Doppler acoustic current meter mapping. In addition, deployment of surface (and perhaps subsurface) drifters is planned, with CODAR measurements of surface velocity on each side of the ice margin. Tracer studies, which have recently been used to identify residence times of subsurface water north of Fram Strait (*Ostlund et. al.*, 1982) will be extended to the MIZ.

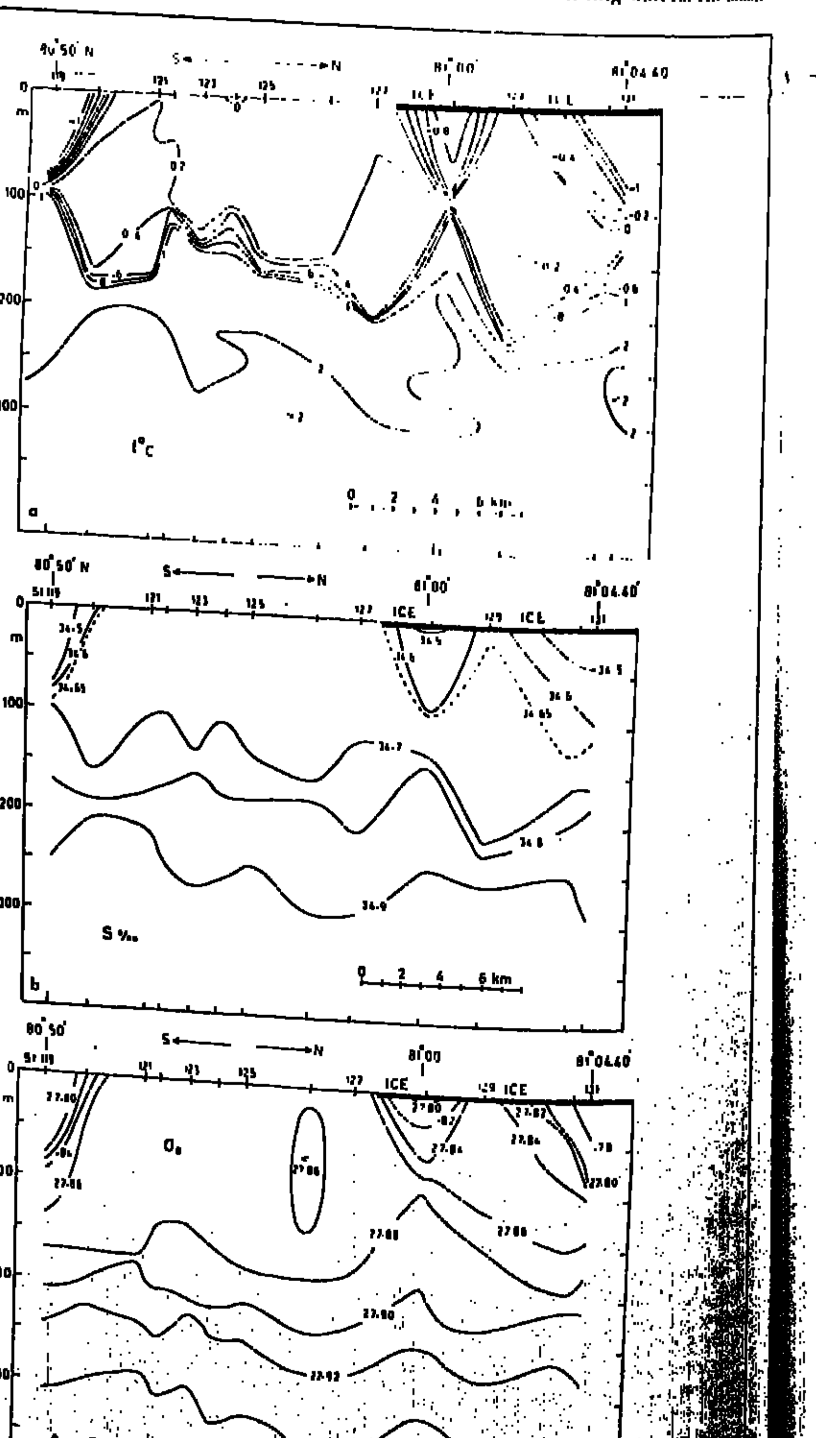


Fig. 1. Sections of temperature, salinity, and σ_t across the Greenland Sea margin zone on December 3, 1977, from *Buckley et. al.* (1979).

Biology

In high latitude biological systems, the ice edge region has higher levels of primary productivity than surrounding waters. *Alexander* (1981) shows that over a third of the total primary productivity in the southeast Bering Sea comes in the single month of May, coinciding with the ice edge bloom. Associated with the bloom is a concentration of marine mammals and birds at the ice edge, with some species adapted specifically to the ice-edge habitat. There are several competing hypotheses for the presence of the bloom, among them: (a) a benevolent environment furnished by a shallow, high-nutrient, mixed layer stabilized by melt water; and (b), increased nutrient levels associated with ice-edge upwelling. Recent work describing the halocline of the Arctic Ocean (e.g., *Aagaard et. al.*, 1981) has emphasized the role of the broad Arctic shelves in maintaining the cold, saline layer of water that separates the relatively fresh Arctic mixed layer from underlying Atlantic water. Presumably, modified shelf water upwelled by processes at the ice edge could supply the needed elevated nutrient levels. If such upwelling is intermittent, the biological signal from each event may provide a 'memory' that is lacking in measurements of the physical properties alone.

Biological measurements in MIZEX will include phytoplankton biomass, phytoplankton species, nutrients, zooplankton biomass and diversity, and a variety of chemical components.

Acoustics

The acoustic climate of the MIZ is complex. Ice itself is noisy in the region where surface wave energy is attenuated by jostling and fracturing of ice floes. Ambient levels are highest at the ice edge but fall off faster in the iceward direction, an effect attributed by Diachok (see *Andersen et. al.*, 1980) to much higher reflection losses at the ice–water interface compared with the open sea surface.

The sound-speed profile is subject to large variations caused by frontal and eddy structure in the MIZ; these variations degrade horizontal coherence of acoustic wave fronts, and therefore the performance of directional acoustic arrays. Since acoustic tomography is potentially an important tool for measuring eddy structure in the MIZ and because synoptic ice-roughness mapping is possible by acoustic backscatter techniques, it is important to determine variability and predictability of sound-speed structure.

Acoustic measurements in MIZEX will include fixed and free drifting sonobuoy arrays, ambient noise including directional information, a tomography experiment, plus seismic reflection and refraction experiments.

Modeling

Credible models of MIZ processes across the whole range of disciplines is a major goal in the MIZEX effort. A partial list includes: sea-ice radiation, thermodynamics, ridging, breaking, and rheology; atmospheric and oceanic boundary layers; eddy generation; frontogenesis and maintenance of fronts; quasisteady, mesoscale circulations in atmosphere and ocean; fine structure and cross-frontal mixing; biological processes; internal waves; sound path and acoustic tomography; and many others.

In addition to their role as end products, models will be used prior to the experiment and in the field to optimize sampling strategies.

Organization and Planned Field Work

The experiment's basic organizational body, the MIZEX Science Group, consists of seven 'Discipline Chairmen' and nine 'National Coordinators' assisted by executive and logistics managers. The Science Group is responsible for determining overall scientific directions and for serving as liaison between scientists and national advisory and funding agencies. Two project offices and a logistics office have been established, publication of a newsletter has commenced, and a MIZEX Bulletin for presentation and discussion of scientific matters is planned.

The MIZEX 83 field project is scheduled for June–July 1983, beginning in the Greenland Sea north of Svalbard (the precise location will depend on ice conditions). The ice-strengthened research vessel *Polarbjorn* will spend about 6 weeks on site, functioning first as a drifting ice station and then performing measurements in the region just seaward of the ice edge. She will be joined for about ten days by the icebreaker *Polarstern* for cooperative work in and near the MIZ. The Norwegian Polar Institute vessel *Lance* will also perform cooperative measuring programs in the vicinity. A number of fixed-wing aircraft from the United States, Canada, France, Denmark, and Norway will carry out remote sensing missions, and two helicopters will aid scientists in deployment and sampling operations.

MIZEX 84 is a much larger project, with five vessels and numerous aircraft and satellite platforms on hand for most of the 6-week field program in June–August 1984. One ship will serve as a drifting station within the ice pack for the entire experiment. *Johannessen, Hibler, et. al.* (in press) describe the scientific plan in detail.

Experience gained during MIZEX 83 will be used to design the 1984 experiment. Following 2 or 3 years of data assimilation, there will be additional summer and winter experiments in the Greenland Sea.

Operational planning for MIZEX 84 is under way and will be completed at a meeting in Bremerhaven, Federal Republic of Germany, in November 1983. Discipline workshops will be held this spring to encourage input to the planning process from all interested scientists. Specific plans or suggestions should be discussed as soon as possible with the discipline chairmen or national coordinators, whose names and addresses and information on administrative matters may be obtained from Dean Horn, MIZEX Executive Officer, Arctic Programs Code 425AR, Office of Naval Research, 800 N. Quincy Street, Arlington, VA 22217 (telephone: 202-696-4118).

The major U.S. sponsor of MIZEX is the Office of Naval Research with support from the National Science Foundation and the National Aeronautics and Space Administration. Other sponsors include: the German Polar Institute, the Norwegian Polar Institute, Bedford Institute of Oceanography, the National Environmental Research Council of Canada, the Canadian Center for Remote Sensing, and the British Meteorological Office.

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EOS

Transactions, American Geophysical Union

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Subscription price to members is included in annual dues ($20.00 per year). Information on institutional subscriptions is available on request. Second-class postage paid at Washington, D. C., and at additional mailing offices. *Eos, Transactions, American Geophysical Union* (ISSN 0096-3941) is published weekly by

American Geophysical Union
2000 Florida Avenue, N.W.
Washington, D. C. 20009

Cover. LANDSAT image of the sea–ice edge in the Greenland Sea. See The Oceanography Report, this issue. The Greenwich Meridian runs north from the bottom right corner of the image at about 60° to the left of vertical. The eddy-like feature centered near 79°40'N, 3°E, is roughly 90 km across. To the east of the 3°E meridian, warm surface water is apparently advected into the ice pack; while, to the west, ice and cold water are swept toward open water. Eddies along the marginal ice zone are not uncommon in satellite imagery. However, the feature shown here is notable in that it appears to coincide with the bathymetric depression known as the Molloy Deep. (Photo courtesy of N. Untersteiner.)

News & Announcements

Mysteries of Bottom Water

Ocean bottom water has historically represented a constant physical entity to most geophysicists. The ocean floor has long been modeled as a classic isothermal, semi-infinite surface in geophysical calculations. Peter Rhines of Woods Hole Oceanographic Institution recently said about the subject of bottom water, 'We've all been trained to imagine that the deep ocean is steady. . . . It's not so much a belief, but a practice that became a way of teaching' (*Science*, November 12, 1982).

It is now becoming well known that, over thousands of years, bottom water is not as stable as once thought. Large bodies of cold water are not really stable over even a decade. The large bodies move, the water itself is renewed, and as a result, the temperature and salinity of ocean bottom water changes regularly. New data point to a less than steady state condition for the water at the ocean bottom.

It has always been assumed, and recently documented, that the deep sea communicates chemically and thermally with surface water. The surface water is mixed by current action and weather effects also can be translated by deep ocean circulation patterns. A rather important concept that now has become suspect, however, was that bottom water remained unchanged in spite of being replaced regularly. If the temperature is not constant in time, an important boundary condition for many geophysical models is violated. The heat-flow vector can be affected and thus the thermal history of the interface must be modeled accurately. The new studies of deep ocean water could offer the possibility of constructing such a model.

R. A. Kerr recently discussed the North Atlantic data of the Transit Tracers in the Ocean (TTO) program, which were presented at the Ewing Symposium in October 1982 and a recent analysis of temperature and salinity observations along 36°N and 24°N latitudes. He said, 'This water was definitely different, which ran counter to the assumptions of the past 100 years of oceanography. This first detection of changes in the presumably immutable deep sea should aid the understanding of how the ocean manages to renew the water of even its deepest recesses.' (*Science*, Nov. 12, 1982).

The studies being done can continuously be updated and can make reference to the surveys made during the International Geophysical Year (IGY) in 1958. The TTO program is a broad study to track the depth penetration of products of nuclear fallout, aerosol propellants, and the like in the oceans. Temperature and salinity data obtained during TTO cruises in the North Atlantic indicated that all water deeper than a few hundred meters north of 50°N latitude and south of Iceland has become a few parts per thousand less saline, and a few tenths of a degree colder. These data are samples of water that originates from the Labrador, Greenland, and Norwegian Seas and enters into the deep Atlantic.

The survey along 36°N and 24°N followed the tracks of IGY surveys. The water at depths between 500 and 3000 m has become warmer by tenths of a degree Celsius. But above 500 m and deeper than 3000 m, extending to the ocean floor, the water was observed to be colder. How these changes might be related to those found in the North Atlantic is not known.

The changes observed are small relative to changes that drive ocean circulation. Nonetheless their magnitude must be known and their trends plotted accurately in time. Potentially also there could be a great deal to learn from these findings about the interaction between the atmosphere and the deep ocean.

—*PMB*

Laser Sounding

Hydrographic surveying along the coastline must be done frequently because ocean bottom topography is under constant change. In a recent discussion in *Naval Research News*, M. B. White of the Office of Naval Research compared the traditional shipboard acoustic sounding method with the new Hydrographic Airborne Laser Sounder (HALS) being developed for the Navy and the National Ocean Survey. The shipboard system can be described by two words: slow, costly. According to a recent summary of White's discussion (*Lasers & Applications*, December 1982), the Defense Mapping Agency, which produces most civilian and military charts in the United States, now has a 200 ship-year backlog. The new HALS system will be 6 times less expensive to operate and 100 times faster. The questions remaining now are related to the type of airborne laser system that can perform the task, in a field of rapidly changing technology.

Sounding the bottom along coastlines can be done efficiently by a small, fixed wing aircraft carrying a state-of-the-art laser system that weighs about 600 kg. As an aircraft flies along an electronically positioned grid system, a laser emits pulses in the visible light region. The pulses are reflected both from the ocean surface and bottom, the difference being the slant depth. The time delays of the two reflected pulses must be measured with extraordinary precision. To achieve a hydrographic depth accuracy of ± 30 cm the temporal laser pulse width must be on the order of about a nanosecond. For civilian requirements a repetition rate of approximately 400 Hz is acceptable. There are several categories of laser—solid state, metal-vapor, and gas types—that can meet the requirements. The types described by White include solid state green, copper-vapor, eximer, and UV-pumped lasers.

The lasers are new, and the techniques to make them perform are being updated regularly. For example, the solid-state neodymium-doped yttrium aluminum garnet (Nd: YAG) laser normally emits a continuous, rather than pulsed, beam in the near infrared region. For hydrographic sounding the frequency of the output is doubled, the cavity is Q-switched to emit pulses, and the pulse is narrowed by a cavity dumper. Other solid state lasers now being tested can be tuned to emit over a range of wavelengths.

Whether of the solid state or (for higher repetition rates) gas medium type, the new lasers employ mode-locking principals. These systems employ state-of-the-art techniques such as cavity dumping, tunable dye laser intermediate stages, and other methods to shape the pulses to a nanosecond or shorter width. For example a high-Q resonant cavity is placed in the system, and pulses are stored until a sufficient peak intensity is achieved. Fast "dumping" or release systems are used to extract very short pulses.

The color ranges required for hydrographic purposes are in the blue-green (deep ocean) or longer wavelength (shallow waters) spectrum. At green to yellow-green wavelengths the clouds algae-laden waters are relatively clear. Of course, tunable lasers are used, but there are a number of other laser-spectral tricks to produce pulsed output in the vicinity of 500 nm. For example so-called wavelength conversion methods such as employing successive Raman-effect upshifts or downshifts can be efficient for gas laser systems.

The new systems will begin to be operative in the mid 1980's. A new variety of lasers are to become available at that time for an instant upgrade.—*PMB*

Ocean Data Tapes

Magnetic tape copies of the two data sets used to prepare the *Southern Ocean Atlas* (*Eos*, August 3, 1982, p. 595) are available from the National Oceanographic Data Center (NODC).

The atlas data set is a screened and edited set of hydrographic station data that includes 6,313 stations. The grid point data set was produced by interpolating the hydrographic data to the points of a circumpolar grid system between 30°S and 80°S with 47 standard levels in the vertical direction.

Data tapes cost $110 for each set. For additional information, contact NODC, NOAA/NESDIS E/OC21, 2001 Wisconsin Avenue, N.W., Washington, DC 20235 (telephone: 202-634-7500).

Earthquakes

Date	Time, (GMT)	Magnitude	Latitude	Longitude	Depth of Focus	Region
Jan. 8	1121	$6.5m_b$	16.24°S	173.40°W	shallow	Tonga Islands
Jan. 17	1241	$7.0M_s$	38.09°N	20.19°E	9 km	Ionian Sea
Jan. 24	0818	$6.7M_s$	16.28°N	94.98°W	38 km	southeastern Mexico
Jan. 24	2309	$6.5M_s$	13.00°N	93.04°E	shallow	Andaman Islands

Information contacts: National Earthquake Information Service, U.S. Geological Survey, Stop 967, Denver Federal Center, Box 25046, Denver, CO 80225 USA.

Meteoritic Events

Meteorite fall: Tennessee, USA, January 28.

Fireballs: Germany (2), Poland, Colorado, Oregon (2), Washington.

Meteorite fall: Maryville, Tennessee, USA (35.80°N, 84.01°W). A brilliant fireball was observed in the Knoxville, Tennessee, area early January 28. On January 29, a resident of Maryville, 30 km S of Knoxville, found a meteorite in a small, recently-formed crater. The equidimensional and roughly softball-sized meteorite had a mass of 1.442 kg, a smooth ablation surface, and a fusion crust less than 1 mm thick. Lawrence Taylor reported that classification work was in progress, but the meteorite appeared to be an ordinary chondrite. A fragment of roughly 180 g was sent to Battelle Northwest Laboratory in Richland, Washington, for counting of short-lived, low-level radioactivity. No other pieces of this meteorite are known to have been recovered.

Information contacts: Lawrence Taylor, Department of Geological Sciences, University of Tennessee, Knoxville, TN 37916 USA.

Methane Ocean On Titan?

There was an impressive list of names on a recent scientific communication that argues for the existence on Titan of an ocean of liquid methane (CH_4) perhaps several hundred meters deep. C. Sagan and S. Dermott with helpful comments by S. Ostro, S. Peale, C. Yoder, W. Thompson, S. Squyres, G. Pettengill, P. Gierasch, and B. Khare speculate that such a methanic ocean, with its Saturnian tides and its tholinian floor, should exist all over Titan's surface; it should unless, they conclude, there is the 'distracting coincidence [that] . . . the position of the surface of Titan [is] . . . near the liquidus in the CH_4 phase diagram [and, consequently, there is] . . . almost no methane ocean at all' (*Nature, 300*, 731, 1982).

We know very little about Titan and its surface; the way of checking into Sagan and Dermott's ideas appears to rest on the interpretation of radar reflectivity data. Preliminary attempts to obtain radar data were made in 1979 with the 305-m Arecibo telescope, but only broad limits resulted. The next opportunity for a measurement at Arecibo comes in the 1990's. Of course, the ideal circumstance would be to send spacecraft equipped with a radar reflectometer for a Titan flyby.

One of the reasons that calculations of the type done by Sagan et al. can yield results of such wide variance—a deep methane ocean or no ocean at all—is that the astronomical constants for Titan upon which the geophysical calculations are based are not well enough determined. They are, however, many orders of magnitude better determined than they were a few years ago, before the United States space exploration program. The values are good enough to work with now, which could not be said even 10 years ago.

The factors about Titan's physical figure are not at all related to the organic, possibly biochemical, arguments often associated with the first author of the paper, Carl Sagan. One cannot get away from the organic nature of the main constituent, methane, which with ammonia and water is believed to compose Titan's icy mantle; Titan probably has a rigid, rocky core, however. There is included in the note a suggestion of Sagan's tholin ideas, which describe the interaction of UV light and charged particles with Titan's atmosphere to produce a class of dark organic solids that, he argues, coat the land (if there is any) and the submarine surfaces. But, that Titan probably is composed of pure, virgin, abiogenic matter seems to hold. The problems of doing geophysical calculations on Titan stem from factors such as the nature of Titan's orbit and whether or not Titan's interior has relaxed in its lifetime to a state of near-hydrostatic equilibrium. Titan has a comparatively high orbital eccentricity (e = 0.0289), and it is not known yet whether Titan is in synchronous rotation.

Keeping in mind that Titan's density distribution (the mean density of Titan is 1.88 ± 0.01 g cm^{-3}, B. Smith *et al., Science 215*, 504, 1982) is not known, and that various factors such as Titan's solid-body and fluid-ocean (if there is one) rigidities are also unknown, Sagan et al. describe the difficulties that arise from known values of Titan's eccentricity. Titan's orbit is far from being circular, and the time constant (Γ) for the decay of an eccentric orbit used by Sagan et al. is

$$\Gamma = 2/21\ (M_t/M_s)\ (a/R)^5\ Q/nK_2$$

where M_t and M_s are the masses of Titan and Saturn; a is the seminajor axis of Titan's orbit; R its radius; and n, K_2 and Q the critical unknowns: the mean motion, the Love number, and the specific dissipation function, respectively. To have a decay time of less than 4.6 billion years (presumably the age of the solar system), Q, it turns out, must be greater than 200, which would be consistent with the existence of a deep ocean completely covering Titan's surface.

Sagan et al. note that Titan's rotation is such that one sector of its surface is directed toward the empty focus of its orbit. The tidal bulge is directed toward Saturn, and thus the tide oscillates across the surface. They argue that the energy losses due to these oscillations should tend to dampen the orbital eccentricity; as they state it, 'the present, comparatively high value of e is difficult to understand.'

Why argue for a methane ocean on Titan? Sagan and Dermott note that the surface conditions (T = 95 K, P = 1.6 bar) on Titan are suitable thermodynamically to stabilize liquid methane. Data from the Voyager 1 spacecraft suggest that methane abundance in Titan's lower atmosphere is better than 0.19 of saturation, and by comparison with the figures on the earth's H_2O atmospheric saturation, methane should begin to condense out (rain). Comparison with the earth's ratio of water in the atmosphere to water in the oceans (a factor of 10^4) suggests that Titan's oceans, if they exist, are deeper than 100 m. The present high eccentricity of Titan's orbit around Saturn would be consistent with a methane ocean deeper than 400 m.—*PMB*

Meteorite Find Yields Carbon

In the new cache of meteorites recently found in Antarctica, 28 of the 31 discovered are carbonaceous chondrites, a type of meteorite rare for its carbon content. According to the National Science Foundation (NSF), the meteorites were discovered at the Pecora Escarpment, the southernmost exposure of rocks of the Pensacola Mountains. Antarctic conditions keep the meteorites nearly free of terrestrial organic contamination, making the meteorites' extraterrestrial organic compounds especially valuable to researchers.

According to NSF, the discoverers termed the recent find 'as good as' the 1977 discovery at Allan Hills, in Victoria Land, of the largest meteorite ever found in Antarctica, one weighing 407 kg. In that year, only about 25 of the world-supply of 2000 meteorites were carbonaceous chondrites.

Books

Advances in Geology of the Porphyry Copper Deposits: Southwestern North America

S. R. Titley (Ed.), The University of Arizona Press, Tucson, xiv + 560 pp., 1982, $35.00

Reviewed by Stephen E. Kesler

This book summarizes recent advances in information on the porphyry copper deposits of southwestern North America. It is a sequel to an earlier summary volume published by the same group in 1966. The new volume is indispensable for anyone interested in copper deposits and a valuable reference for those working in fields ranging from the petrology of silicic igneous rocks to the tectonic evolution of western North America. The volume is particularly significant because porphyry coppers are by far the most important class of deposits in terms of global copper reserves and, most importantly, because southwestern North America contains an unusually large number and variety of these deposits.

In using this volume it is important to keep in mind that 16 of the 27 chapters were written largely or entirely by geologists from industry whose first responsibility is to exploration and production rather than to research and publication. It is no small task for these geologists to obtain management permission to write papers about their deposits or, in fact, to find time to write. It is an even tougher job to coordinate a volume such as this with contributions from academia, industry, and government, and we can be grateful to editor Spencer Titley for his commitment to this project.

The volume is divided into two parts. The first part contains 13 articles on selected topics in porphyry copper geology including general studies of the grade, tonnage, and economics of worldwide porphyry copper deposits as well as more specific, southwestern North America–oriented papers on the geologic setting of the deposits; their thermal evolution, fracture, and dike patterns; alteration mineralogy, chemistry, character, and evolution; associated skarn alteration and mineralization; leached cappings; and geochemical exploration techniques. This section also includes more specific papers on primary metal dispersion haloes around the Kalamazoo deposit, the geochemistry of sulfur and copper at the Ray deposit, and the petrology of the Ray igenous rocks. Much, though not all, of the information in this section has appeared in print previously, so the value of these papers must lie in their success in drawing new and useful conclusions. Particular success along this line is seen in the chapters on alteration mineralogy and on leached cappings. The second section includes 13 papers on deposits that had not been described previously in any detail or for which significant new data had become available within the last decade. The papers in this section vary widely in quality, but all provide at least a basic geologic framework for the deposits. Particularly commendable in this section are the attempts that have been made to provide information on the relation between copper and molybdenum grades and related geologic features. Comprehensive descriptions such as this are necessary if we are to develop truly realistic genetic models for these deposits.

Considered in its geologic and editorial context, this volume cannot be criticized to any real extent. Its broadest shortcoming, the failure to propose genetic models for the processes and deposits that are discussed, is actually a realistic reflection of the extreme complexity of these deposits and our still limited research progress on them. The lack of a chapter on geophysical exploration methods for these deposits is in part made up for by information in the recently published 75th anniversary volume of the Society of Economic Geologists. Typographic and illustration errors are remarkably scarce.

This volume will no doubt remain a valuable source of data for students of late magmatic mineralizing processes for many years to come and, it is hoped, a starting point for a third, and final (?) summary volume near the end of the next decade.

Stephen E. Kesler is with the Department of Geological Sciences, University of Michigan, Ann Arbor.

New Publications

Items listed in New Publications can be ordered directly from the publisher; they are not available through AGU.

Astronomy and Astrophysics Abstracts, vol. 31, Literature 1982, Part 1, S. Bohme, W. Fricke, H. Hefele, I. Heinrich, W. Hofmann, D. Krahn, V. R. Matas, L. D. Schmadel, G. Zech (eds.), Springer-Verlag, New York, 1982.

Cartographic Drawing with Computers, P. Yoeli, Computer Applications Special Issue, vol. 8, Department of Geography, University of Nottingham, Nottingham, U.K., viii + 137 pp., 1982, $12.

Chemistry of the Unpolluted and Polluted Troposphere, H. W. Georgii and W. Jaeschke (eds.), Proceedings of the NATO Advanced Study Institute held on the Island of Corfu, Greece, September 28-October 10, 1981, D. Reidel, Boston, ix + 509 pp., 1982, $63.00.

Earthfire: The Eruption of Mount St. Helens, C. Rosenfeld and R. Cooke, MIT Press, Cambridge, Mass., vix + 155 pp., 1982, $25.00.

Electromagnetic Sounding Interpretation Data Over Three-Layer Earth, R. K. Verma, IFI/Plenum, New York, vol. 1, x + 338 pp.; vol. 2, v + 546 pp., 1982, $165 each.

Fertilization of Dryland and Irrigated Soils, J. Hagin and B. Tucker, *Advanced Series in Agricultural Sciences*, vol. 12, Springer-Verlag, New York, viii + 188 pp., $39.50.

Fortran Program for the Computation of Gravimetric Quantities from High Degree Spherical Harmonic Expansions, R. H. Rapp, Report 334, Ohio State University Department of Geodetic Science and Surveying, Columbus, iv + 23 pp., 1982.

Geological Evolution of the Earth During the Precambrian, L. J. Salop, translated by V. P. Grudina, Springer-Verlag, New York, xii + 459 pp., 1983, $65.80.

Geology of Offshore Ireland and West Britain, D. Naylor and P. Sannon, Graham and Trotman, London, 1982.

Global Atlas of Sea Surface Heights Based on the Adjusted Seasat Altimeter Data, R. H. Rapp, Report 33, Ohio State University Department of Geodetic Science and Surveying Columbus, v + 63 pp., 1982.

High-Pressure Research in Geophysics, S. Akimoto and M. H. Manghnani (eds.), *Advances in Earth and Planetary Sciences*, vol. 12, D. Reidel, Boston, xiv + 632 pp., 1982.

Correction

The price of *Evaporation Into the Atmosphere: Theory, History, and Applications*, by W. Brutsaert, D. Reidel, Hingham, Mass., was incorrectly listed in *Eos*, Dec. 21, 1982, p. 1223; the correct price is $34.95.

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Unusual opportunity for Ph.D. Hydrologist. Tarleton State University, part of the Texas A&M University System, has been authorized to offer a B.S. Degree in Hydrology beginning with the Fall 1983 Semester. This will be the only such degree in the state of Texas and one of very few in the nation. The program will be administered by a Director in conjunction with an advisory board of outstanding professionals. The Director we are seeking must be an enthusiastic individual with extensive experience in and knowledge of the field of hydrology to develop this program to regional or national prominence. This will be a tenure-track appointment, rank and salary negotiable, and includes administrative release time. Substantial funding has been awarded for facilities construction.

Applicants should send a resume and the names of three references to: Dr. Thomas C. Hinkson, Head, Department of Physical Sciences, P.O. Box T-09, Tarleton State University, Stephenville, Texas 76402. Telephone 817/968-9143.

The deadline for application is April 15, 1983.

Tarleton State University, enrollment 4,300, offers Bachelors and Masters degrees, is located in Stephenville, Texas, a progressive city of 13,000 people, 65 miles southwest of the Dallas-Ft. Worth Metroplex, and is an affirmative action, equal opportunity employer.

Naval Postgraduate School. The Department of Oceanography invites applications for the position of Adjunct Research Professor in the Ocean Turbulence Laboratory. The successful applicant will be responsible for the organization and execution of oceanic turbulence measurements as well as the interpretation and reporting of the obtained data. The position requires a Ph.D. or equivalent in Physical Oceanography, 3 years of post-doctoral experience with oceanic measurements and data interpretation, and some familiarity with turbulence instrumentation. The Ocean Turbulence Laboratory is actively engaged in the measurement and interpretation of oceanic turbulence data from a variety of environments obtained with several types of vehicles. The successful candidate will be expected to contribute to the growth and development of the scope of the research performed by the laboratory.

Applicants should send a resume, statement of research record and interests, and the names of at least three references to Prof. Thomas R. Osborn, Code 68Or, Naval Postgraduate School, Monterey, CA 93940.

Applications will be considered until March 15, 1983.

An Equal Opportunity/Affirmative Action Employer.

Geophysicist/University of Montana. The Geology Department of the University of Montana is inviting applications to fill a tenure track position at the assistant or associate professor level with a specialized area of geophysics beginning Sept. 1983. Teaching and research responsibilities at the undergraduate and graduate levels. Research interests should combine solid earth geophysics and geology.

Applicant must have the Ph.D. degree or expect completion by summer 1983. Those interested should send a letter of application, resume, an outline of teaching and research interests and other relevant material. The applicants should arrange to have at least three letters of recommendation sent to: Arnold J. Silverman, Chairman, Department of Geology, University of Montana, Missoula, MT 59812.

The deadline for applications is March 15, 1983.

The University of Montana is an affirmative action/equal opportunity employer.

Faculty Position/Department of Geology, University of Illinois at Urbana-Champaign. Applications are solicited for a tenure track assistant professor position in experimental rock physics. The position is expected to be filled by August 1983. Salary is open depending upon experience. We are seeking a creative individual who is interested in either brittle or ductile behavior of rocks and their geological applications. An earned Ph.d. is required. The Department of Geology, the Materials Research Laboratory and the Engineering College of the University together offer excellent research facilities for rock physics studies. For equal considerations, interested individuals should send curriculum vitae, list of publications, research interests and the names of three or more references by March 5, 1983 to:

Albert T. Hsui
Department of Geology
University of Illinois at Urbana-Champaign
1301 West Green Street
Urbana, Illinois 61801
217-333-7732.

University of Illinois is an equal opportunity/affirmative action employer.

Postdoctoral Position/Seismology. Postdoctoral support in seismology is tentatively available for up to a 24-month period. Seeking a recent Ph.D. with interest in regional seismic wave/surface wave propagation. Applications should be sent to: Dr. Robert G. Hermann, Department of Earth & Atmospheric Sciences, St. Louis University, Box 8099, St. Louis, MO 63156. 314-658-3120.

St. Louis University is an affirmative action/equal opportunity employer.

Atmospheric Scientist-Programmer/University of Nevada System. The Desert Research Institute has an opening for an Atmospheric Scientist-Programmer within the Atmospheric Sciences Center. The individual will take part in the processing, analysis, and interpretation of aircraft cloud physics data and data collected with radar, radiometer, and lidar remote sensing instruments in cloud physics and weather modification research projects. Initial emphasis will be on developing computer-generated-graphics data display capabilities at DRI. Emphasis will then shift to data analysis and interpretation and publication of results. Opportunities exist for developing own research projects. Desirable qualifications include a Ph.D. in atmospheric sciences with 2 to 5 years experience in computer-assisted aircraft and/or remote sensing data display and analysis. Strong candidates with the M.S. degree in atmospheric sciences or related fields of physical science with extensive relevant experience will also be considered and are encouraged to apply. The salary will be attractive and is negotiable, full benefit package is included. Send letter of application, a complete resume stating particulars of education and experience, and names, addresses, and telephone numbers of three individuals who can comment knowledgeably about your capabilities, postmarked by April 1, 1983, to: Mrs. Harrison, Personnel Office, Desert Research Institute, University of Nevada System, P.O. Box 60220, Reno, Nevada 89506.

An Affirmative Action/Equal Opportunity Employer.

STUDENT OPPORTUNITIES

Graduate Research Assistantships in Earthquake and Exploration Seismology/University of Kansas. The computer acquisition of digital seismograms for a 20 + station seismic network covering the southern end of the Central North American Rift System and the development of techniques for Very High Frequency (500–1000 Hz) reflection seismology provide excellent opportunities for graduate study at the M.S. or Ph.D. level. For further information and/or application, please write:

Dr. George H. Rothe, Chairman
Geophysics Program
Department of Geology
University of Kansas
Lawrence, Kansas 66045
(913) 864-4974.

Graduate Scholarships in Geophysics/University of Wyoming.

Amoco and Chevron Fellowships
M.S. and Ph.D. levels
Up to $10,500/year plus tuition
Research support
Research and Teaching Assistantships
$5,500–7,200/academic year
$2,500 summer stipend
Tuition
Hill Fellowships
Variable stipends
Areas of geophysical research at Wyoming:
Reflection seismology
Gravity and magnetic potential field studies
Physical properties
Paleomagnetism and rock magnetism
Thermal processes
Crustal structure and magnetism
Tectonic modeling
Seismic data processing
Contact: Dr. Kevin P. Furlong
Dept. of Geology/Geophysics
University of Wyoming
PO Box 3006 Univ. Station
Laramie, WY 82071
307/766-4379.

Graduate Fellowships in Coastal and Continental Shelf Sedimentation. The Geology Department of Dalhousie University invites applications for graduate fellowships leading to M.Sc. and Ph.D. degrees with specialization in the field of coastal and continental shelf sedimentation. Potential research areas include shoreface and sediment processes, instrumentation for sediment transport studies and construction of coastal facies models. Opportunities exist to take part in the upcoming Canadian Coastal Sediment Study and to gain scientific cruise experience on research vessels from Bedford Institute of Oceanography. Awards cover a calendar year stipend and are valued, after fees are deducted, between $6500–$8000. For further information or application please write:

Dr. R. Boyd
Geology Department
Dalhousie University
Halifax, Nova Scotia
CANADA B3H 3J5.

Graduate Research Assistantships/Cold Regions Science & Engineering. Thayer School of Engineering at Dartmouth College and the US Army Cold Regions Research & Engineering Laboratory invite applications from students interested in ME, MS, Ph.D. & DE programs with specialties in the cold regions. Potential research areas include: geophysics of snow, ice & frozen ground; hydraulics and hydrology in cold regions, polar marine engineering; and materials science of ice and other frozen materials.

Undergraduate majors in engineering, physics, and geophysics are encouraged to apply. For admission requirements and more detailed information contact:

The Dean of Thayer School of Engineering
Dartmouth College
Hanover, NH 03755.

SERVICES, SUPPLIES, COURSES, AND ANNOUNCEMENTS

INSTITUTE ON FLOODS

June 27–July 1, 1983

Colorado State University
Fort Collins, CO

Special written lecture notes for prediction estimation and forecasting of floods. Well known methods based on statistics, mathematical modeling and empirical methods will be described.

Lecturers:

R. Clark	T. Sanders
W. James	H. Shen
J. Salas	V. Yevjevich

Fee: $600.00

Limited funds available from UNESCO for partial tuition sponsorship for participants from developing countries.

Contact:
Carolyn Frye
Institute of Conferences
Colorado State University
Fort Collins, CO 80523
303-491-6222.

AGU

Gelhar Receives Horton Award

Citation

The field of subsurface hydrology was perhaps the last area of hydrology to abandon strict determinism and to incorporate into its analysis the ample uncertainty arising from the structure and properties of the medium. Recent years have seen an explosion of activity in this area, however, made possible in large part by the pioneering contributions of this year's Robert E. Horton Award winner.

His early papers on the spatial variability of aquifer parameters established a general framework for the treatment of random hydraulic conductivity variations in an aquifer by means of stochastic differential equations. This provided the basis for his important later work on the stochastic theory of macrodispersion in nonuniform porous media. The impact of his contributions is evident from the large number of recent symposia and publications devoted to the stochastic description of groundwater flow and from the fact that his work is referred to extensively in the literature.

He did all his formal academic work at the University of Wisconsin and first joined the MIT faculty in 1964. He left MIT for the New Mexico Institute of Mining and Technology in 1975 and rejoined the MIT faculty this past September. He is a personal friend of long standing and I can think of no one to whom I would rather present the 1982 Robert E. Horton Award than Lynn W. Gelhar.

P. S. Eagleson

Acceptance

It is a pleasure to receive this award not only as an indication of individual achievement but also as recognition that stochastic subsurface hydrology has become well established as a legitimate area of research. This has not always been the case. Ten years ago when I first began to work in this area one of the leading groundwater researchers strongly advised me that the stochastic approach was unnecessary because groundwater flow is completely described by deterministic equations. Needless to say I did not heed that advice.

I want to acknowledge the contributions of colleagues at New Mexico Tech and MIT who have worked with me and had an important influence on my thinking in this area. Also, I have been fortunate to have had a succession of sharp graduate students who have worked with me in this area and have benefited from some stimulating competition from individuals like Gedeon Dagan.

I would like to offer some of my perspective on the area of stochastic subsurface hydrology. To me this is more than a question of probabilistic theory or computational methodology. In my view the motivation for a stochastic approach presents itself rather strongly in field observations of the natural variability of properties such as hydraulic conductivity. The key element of the stochastic approach is the coupling of that natural variability with well-established physics which is based on controlled laboratory experiments. The goal is a quantitative description of the controlling, large-scale processes which determine field-scale behavior. The stochastic approach expresses that large-scale behavior in terms of the expected value, and second moment analysis gives a measure of the variability of the prediction about the mean.

The field of stochastic subsurface hydrology has benefited from a diversity of methodologies; comparisons of results have made it possible to develop confidence in the reliability of the various methods. For example, in the very important case of solute transport three distinctly different methods of analysis by independent researchers (*Dagan*, 1982; *Gelhar and Axness*, 1983; *Winter*, 1982) all have produced essentially the same result for the macroscopic dispersion coefficient. The results in this case have important practical implications. First of all, the theory shows that the mean behavior, as reflected in the macrodispersion coefficient, is strongly influenced by the variance of the logarithm of hydraulic conductivity. This is in contrast to the head prediction problem where mean behavior is only weakly dependent on log-conductivity variance. Second, near the source, the mean concentration field is not described by the classical convective dispersion equation; the dispersion coefficients depend on displacement distance, and higher order derivatives produce skewed concentration distributions. Also, the concentration variance is very large near the source. When we look carefully at field observations, these same features are apparent.

This discussion of the solute transport problem illustrates the state of the art in stochastic subsurface hydrology. Our methods have developed to the stage that we can use the results with some confidence to look carefully at large scale field behavior. In doing so we discover some nonclassical behavior which seems to be reflected in field observations. The results of the stochastic analyses of subsurface transport processes point to the need for a more balanced approach which integrates geologic information, field experimentation, statistical analysis and numerical simulations. In my view that approach is essential to quantitative understanding of the field-scale phenomena which are important in problems of resource development and environmental protection in the aqueous underground.

References

Dagan, G., Stochastic modeling of groundwater flow by unconditional and conditional probabilities, 2, The solute transport, *Water Resour. Res.*, *18*, 835–848, 1982.

Gelhar, L. W., and Axness, C. L., Three-dimensional stochastic analysis of macrodispersion in aquifers, *Water Resour. Res.*, *19*, in press, 1983.

Winter, C. L., Asymptotic properties of mass transport in random porous media, Ph.D. dissertation, Univ. of Ariz., Tucson, 1982.

Meetings

Announcements

Atmospheric Contaminants

The deadline for submission of abstracts for the World Meteorological Organization Technical Conference on Observation and Measurement of Atmospheric Contaminants (TECOMAC) is March 31, 1983. The meeting will be held October 17–21, 1983, in Vienna, Austria. A major objective of the meeting is to establish the state of present knowledge of man-induced and natural chemical and physical atmospheric parameters and of how they affect climate and the environment.

The organizing committee will select papers on topics that include chemical climatology and its evolution; significance of air chemistry observations for understanding and predicting the state of the environment and climate variations; observation and measurement of long-lived and reactive gases, aerosols, turbidity, dry deposition, and chemical constituents in precipitation and organic contaminants; instruments, analytical techniques (including isotope and nuclear), standardization, quality assurance, and data evaluation techniques; and interaction of atmospheric constituents with adjacent environmental media.

Abstracts may be forwarded to the WMO Secretariat, Attention: C/ENV, Case postale no. 5, CH-1211 Geneva 20, Switzerland. They must be written in English and should not exceed 200 words.

The conference is cosponsored by the International Atomic Energy Agency, UNEP, and the Austrian Zentralanstalt für Meteorologie und Geophysik.

Attendance is both by invitation and application. Those interested in participating should contact no later than July 1 the registration chairman, John Hulsmann, Grumman Aerospace Corporation, Bethpage, NY 11714 (telephone: 516-575-2054).

Environmental Satellites

A workshop on the uses of environmental satellites will be held March 21–23, 1983, in Santa Barbara, California. Included in the topics to be discussed by panelists from the United States, Canada, and France will be the mission of the new polar-orbiting environmental satellite, NOAA-E, and its sensors, which include first-time instruments on a U.S. satellite that are useful in global search and rescue operations. The launch of the RCA-built satellite from Vandenberg Air Force Base in California is scheduled for March 28.

For additional information on the workshop contact Pam Ramaglia, MS 501, RCA Astro-Electronics, P.O. Box 800, Princeton, NJ 08540 (telephone: 609-426-2713). The workshop is sponsored by NOAA's National Environmental Satellite, Data, and Information Service and by RCA.

Digital Signals

The Acoustics, Speech, and Signal Processing (ASSP) Society of the Institute of Electrical and Electronics Engineers will sponsor the Third ASSP Workshop on Multidimensional Digital Signal Processing in Lake Tahoe, Calif., October 19–21, 1983.

Geophysical Year

New Listings

The complete Geophysical Year last appeared in the December 21, 1982, *Eos*.

A boldface meeting title indicates sponsorship or cosponsorship by AGU.

March 21–23, 1983 Workshop on Uses of Environmental Satellites, Santa Barbara, Calif. Sponsors, NOAA National Environmental Satellite, Data, and Information Service and RCA. (Pam Ramaglia, MS 501, RCA Astro-Electronics, P.O. Box 800, Princeton, NJ 08540; telephone: 609-426-2713).

October 17–21, 1983 Technical Conference on Observation and Measurement of Atmospheric Contaminants, Vienna, Austria. Sponsors, World Meteorological Organization, International Atomic Energy Agency, UNEP, and the Austrian Zentralanstalt für Meteorologie und Geophysik. (WMO Secretariat, Attention: C/ENV, Case postale no. 5, CH-1211 Geneva 20, Switzerland.)

September 23–24, 1983 Models in Geomorphology, Buffalo, N. Y. (Michael Woldenberg, Department of Geography, State University of New York, Buffalo, NY 14260.)

January 23–27, 1984 Ocean Sciences Meeting, New Orleans, La. (Meetings, AGU, 2000 Florida Avenue N.W., Washington, DC 20009.)

August 5–16, 1985 IAMAP/IAPSO Joint Assembly, Honolulu, Hawaii. (Meetings, AGU, 2000 Florida Avenue, N.W., Washington, D. C. 20009.)

September 17–21, 1985 AIPG Annual Meeting, St. Paul, Minn. Sponsor, American Institute of Professional Geologists. (Robert E. Prendergast, General Chairman, 1925 Oakcrest Avenue, Roseville, MN 55113; telephone: 612/636-7744.)

Meeting Report

PNW Region Holds Joint Meeting

The twenty-ninth AGU Pacific Northwest Regional Meeting was held September 15–16, in Fairbanks, Alaska. This was the first time that the meeting was held in Alaska, which, incidently, has the highest per capita AGU membership in the United States. The thirty-third meeting of the Alaska Science Conference (AAAS) was convened jointly (September 16–18) with the AGU meeting. Approximately 550 participants attended the AAAS portion and presented 220 papers; about 150 attended the AGU segment and presented 63 papers. Carl Benson chaired a joint plenary session on 'Geophysics of Alaska's South Coast.'

Special acknowledgement must be given to Maggie Billington who handled the logistics for both meetings. The combined meeting enhanced both events and we anticipate a similar arrangement when Alaska hosts the meeting again.

This meeting report was prepared by Thomas C. Royer *and* Walter R. Johnson *of the University of Alaska, Fairbanks.*

General Tectonics and Tectonophysics

Arctic-Alaska, a two-stage Displaced Terrane

J.F. Sweeney (Pacific Geoscience Centre, Box 6000, Sidney, B.C., Canada V8L 4B2)

One of the oldest ideas for opening the Canada Basin is the rotation of Alaska away from Arctic Canada about a pivot near the Mackenzie Delta. In support of the idea, the basin, formed in latest Jurassic-early Cretaceous time, has weakly lineated magnetic anomalies that appear to radiate from the Mackenzie Delta region. Also, restoring the rotated block achieves a good bathymetric fit and, for late Paleozoic and younger pre-rift age rocks, a good geological fit between northern Alaska and the Arctic Islands.

The rotation hypothesis does not explain structural and metamorphic differences between Devonian and older Paleozoic rocks across the restored boundary between Banks Island and northern Alaska. This reconstruction also places major mid-Paleozoic sediment transport directions within adjacent terranes in opposition, northwesterly in a restored Arctic-Alaska, southwesterly in polar Canada.

In this talk, the known geology of mid- and early Paleozoic rocks is compared along the margins of the restored rift and the anomalous Arctic-Alaska terrane is explained as a block that was displaced southwestwards in mid-Paleozoic time by as much as 2000 km from its initial orogenic site to the north and east of Ellesmere Island.

Eocene Paleolatitudes for the Aleutian Islands

D. STONE (Geophysical Institute, University of Alaska, Fairbanks, Alaska 99701)
W. HARBERT (Stanford University, Palo Alto, California 94305)
T. VALLIER (U.S. Geol. Surv., 345 Middlefield Road, Menlo Park, California 94025)
H. McLEAN (U.S. Geol. Surv., 345 Middlefield Road, Menlo Park, California 94025)

Paleomagnetic data from sets of samples of Late Eocene age from Amatignak, Umnak (Nikolski) and Amlia Islands give mean paleo-latitudes south of their present latitudes, but with error bars permissive of the latitude not having changed with respect to geographic coordinates. The rocks sampled all had clearly defined bedding planes taken to represent ancient horizontal. Samples from Amlia Island were not oriented with respect to azimuth, hence only give information on the magnetic inclination which is of normal polarity. Data from Umnak Island and Amatignak Island show both normal and reversed polarities. Preliminary means corrected for tectonic tilt are:

	D	I	K	α	N	λ	β	Paleo-λ
Amatignak	53	57	22	15	6	51	270	38
Umnak	67	64	23	11	9	47	262	46
Amlia	-	64	27	12	7	-	-	46

D, I, declination and inclination of the magnetic vector, λ, β, lat. and long. of equivalent pole positions.

When these Aleutian data are compared with data from Cratonic N. America they indicate a northward translation and a clockwise rotation of the rocks since their deposition. This is in accord with a late arrival of the terranes of S. Alaska, including the Aleutian Islands.

An Island Arc Gabbroic Complex in southern Ak.

L. E. BURNS (Geophysics Department, Stanford University, Stanford, Ca., 94305)
G. S. PESSEL (A.D.G.G.S., Anchorage, Ak., 99501)
N. SLEEP (Geophysics Department, Stanford Univ.)

Geologic mapping and geophysical anomalies indicate the presence of a narrow, elongate belt (1000 km) of gabbroic and ultramafic rocks in southern Alaska. Although the rocks are bounded by a major suture zone, the Border Ranges fault, and superficially appear to resemble an ophiolite, petrologic and compositional data clearly indicate that these rocks were not formed at a mid-ocean ridge or back-arc basin.

The Nelchina gabbroic complex, the largest exposure in the belt, varies from 2 to 10 km in width, and crops out for 180 km in an east-west trend. The layered gabbroic rocks are in fault contact to the north with the Talkeetna Formation, an early Jurassic volcanic arc, and are fault bounded on the south by the McHugh Complex, a late (?) Cretaceous subduction melange. Detailed mapping at 1:2400 and regional mapping at 1:63360 indicates that the gabbroic complex consists predominately of gabbronorite, but diorite, quartz diorite, and lesser ultramafic rocks occur locally.

Specific features of Nelchina gabbro which indicate a non-ophiolitic origin include a thick sequence of gabbronorites, abundant primary Fe-Ti oxides and iron-rich pyroxenes, very minor olivine, locally abundant late-magmatic hornblende, and close spatial and temporal association with calc-alkaline intrusions; gabbro-quartz diorite migmatites are particularly common.

Comparison with data from the Marianas and Aleutian arcs suggest that the Nelchina gabbroic complex represents part of the basal accumulation of an island arc. A brief examination of ultramafic bodies within the same trend suggest that they too are not ophiolitic, but rather are part of the island arc floor. The most obvious volcanic equivalent, based on location and K-Ar dates, is the Talkeetna Formation to the north. The existence of this non-ophiolitic belt of rocks has important implications for the formation of southern Alaska.

Determination of Rock Mass Deformation Modulus in Closely Jointed Columbia River Basalt

O. C. LANIGAN (Basalt Waste Isolation Project, Rockwell Hanford Operations, Richland, WA 99352)
M. L. CRAMER (Same as Above)
K. KIM (Same as Above)

This paper describes the results obtained to date from a comprehensive laboratory and field investigation being conducted by the Basalt Waste Isolation Project (BWIP) of Rockwell Hanford Operations to determine the rock mass deformation characteristics of Columbia River basalts. The BWIP is in the process of assessing the suitability of the Columbia River basalts located in southeastern Washington as a potential site for a nuclear waste repository.

Understanding of the deformational response of a rock mass in a repository environment is of fundamental importance for repository design. The deformation modulus of basalt was measured by various methods including laboratory core tests, NX borehole jacking tests, and a flat jack test conducted in a 2 m wide by 4.5 m deep horizontal slot in situ.

A comparison of test results implies that the deformation modulus decreased with increasing specimen size in a similar fashion to the rock mass strength. Test results show deformation modulus values of 87, 40, and 20 GPa from laboratory tests of intact core, borehole deformation measurements in a flat jack test, and borehole jacking tests, respectively. Temperature did not appear to affect the modulus values significantly up to 100°C in both laboratory tests and in the flat jack test.

A further field investigation which is currently in progress involves testing of a 2 x 2 x 2 m cube of basalt in a multiaxial loading configuration at temperatures up to 200°C and pressures up to 20 MPa. This test will provide data that will assist in establishing the size dependency of deformation properties of the basalt, which is critically needed for repository design studies.

Constraints on Tectonic Models for the Columbia Plateau From the Age and Growth Rates of Yakima Folds

S. P. REIDEL (Rockwell International, Richland, WA 99352)
K. R. FECHT (Rockwell International, Richland, WA 99352)
R. W. CROSS (Rockwell International, Richland, WA 99352)

The age of deformation and the rate of growth of Yakima folds have been determined by studying the distribution and thickness variations of Columbia River basalt, intercalated sediments, and suprabasalt sediments. Mapping has shown that anticlinal ridges, synclinal basins and a westward tilting paleoslope are the main structural elements of the west and central Columbia Plateau. Thickness variations in the flows, as they cross these structural features, indicate that the anticlinal ridges and synclinal basins began growing in Grande Ronde time (16.5-14.4 mybp) and continued to grow through the Miocene. Suprabasalt sediments show similar variations, and indicate the structures continued to grow in the Pliocene and into the Quaternary.

The rate at which these structures grew can be calculated by using flow thickness variations which essentially record the relief at the time of eruption. These calculations indicate deformation was greatest in Grande Ronde time (>200 m/my) and decreased (<40 m/my) into the Wanapum (14.5-13.5 mybp) and Saddle Mountains time (13.5-10.5 mybp). Suprabasalt sediment thickness variations suggest uplift and subsidence continued into the recent at this low rate.

The age and growth rate constrain tectonic models for the Columbia Plateau. These models must permit fold growth in restricted areas over at least 15.5 my and a decreasing rate of deformation with time.

AN APPLICATION OF NEAR FIELD STATIC TILT FROM SURFACE LOADS

J. F. Lewkowicz (Stone & Webster Engineering Corporation)
P.O. Box 2325
Boston, MA 02107

Experimental results show that it is feasible to measure elastic moduli in-situ using a buried tiltmeter to monitor ground tilt from a surface load. Potential applications for such a technique are the non-destructive evaluation of pavement subgrades and the continuous monitoring of ground deformation during and after large construction projects. In the course of this investigation it became necessary to distinguish the difference between measuring horizontal and vertical tilt. The equations defining these quantities are reviewed. The modification and application of the theoretical expressions to field measurements is presented. The results are relevant in engineering situations where tilt measurements are usually made in the near field, and to crustal deformation studies when near surface tilt measurements are compared to leveling data.

Ahoy!

1 week
March 9
Abstract Deadline
for the
1983 AGU SPRING MEETING
May 30–June 3

Contact AGU Meetings
2000 Florida Avenue N.W.
Washington D.C. 20009
(202) 462-6903 D.C. area

Mark Your Calendar, Now!

Ocean Sciences Meeting

January 23–27, 1984
New Orleans, Louisiana

Meeting Cochairmen:
John R. Apel, *The Johns Hopkins University, Applied Physics Laboratory*, and Richard T. Barber, *Duke University, Marine Laboratory*

To be placed on a special mailing list, write to Ocean Sciences Meeting, AGU, 2000 Florida Avenue, N.W., Washington, D.C. 20009.
Call for papers to be published in *Eos.*

The Climatic Effects of Volcanic Dust and Aerosols in the Upper Atmosphere

Friday, March 18, 1983
8:30 a.m.–5:00 p.m.

National Bureau of Standards Auditorium
325 Broadway, Boulder, Colorado

Sponsored by the AGU Front Range Branch Cosponsored by the Denver/Boulder Chapter, American Meteorological Society

This symposium will bring together prominent researchers in the fields of climatology, meteorology, glaciology and volcanology to summarize the state of knowledge on this subject in an interdisciplinary forum at a level appropriate for a non-specialized, but scientifically literate audience. The meeting is open to the public.

Topics will include
- The history and causes of climatic variations
- Explosive volcanism
- Atmospheric effects and observations
- Climatic and cultural consequences.

Contacts: Jules Friedman and Raymond Watts
U.S. Geological Survey, P.O. Box 25025
Mail Stop 964, Denver, CO 80225
(303) 234-3676 (Friedman) or 234-3493 (Watts).

For further information, see *Eos* Meetings Section, February 15, 1983.

Geochemistry

Gold Content of Rocks of the Fairbanks Mining District, Alaska

D. B. HAWKINS (Geology/Geophysics Program, University of Alaska, Fairbanks, Alaska 99701)

The mean (±1 standard deviation) gold content of the Cleary Standard vein quartz; vein quartz (district wide); schist; and quartz diorite are: 0.342 ± .020 ppm; 5.65 ± 1.54 ppm; 0.361 ± 0.119 ppm; and 3.73 ± 0.682 ppm respectively. These values were obtained from 2,441 gold analyses of rocks of the Fairbanks District done as part of the joint University of Alaska-U.S. Geological Survey Heavy Metals Project. The above values were derived by using the geochemical sampling constant of Ingamells and Switzer, coupled with computer sampling experiments. This approach was required because of the Poisson distribution followed by gold in these rocks. Mean gold values for other rock types are also reported, but the number of samples was insufficient to provide a useful measure of the standard error of the mean.

The commonly used atomic absorption (AA) analytical method, with aqua-regia digestion, gives results for gold in good agreement with the fire assay method. Both methods gave values that were higher than those returned by the AA method and HBr-Br_2 digestion.

Possible trace element associations among the transition metals; B, Ba, Zr; Sr, Y; Au, Sb; Hg, Pb, are suggested by principal components analysis. These associations are tentative because of the serious sampling problems inherent in this study.

Geochemistry of the Capps and Waterfall Coal Beds, Tyonek Formation, Capps Coal Field, Cook Inlet Region, Alaska

RONALD H. AFFOLTER (U.S. Geological Survey, Box 25046, M.S. 972, Denver Federal Center, Denver, Colorado 80225)
GARY D. STRICKER (U.S. Geological Survey, Box 25046, M.S. 972, Denver Federal Center, Denver, Colorado 80225)

Nineteen samples from the Capps and Waterfall coal beds in the lower Oligocene to middle Miocene Tyonek Formation, Capps coal field, Cook Inlet region, Alaska, were collected by the U. S. Geological Survey in order to assess coal quality. These samples consist of 15 core and 4 face channel samples from the Tyonek B-5 quadrangle. Proximate and ultimate analyses; heat-of-combustion, air-dried-loss, and forms-of-sulfur determinations; as well as major- and minor-oxide and trace-element analyses were performed on each sample. The apparent rank for both the Capps and Waterfall coal beds ranges from lignite A to subbituminous B.

Sulfur content ranges from 0.12% to 0.33% and ash content ranges from 9.31% to 40.3%. Selected elements of environmental concern have the following ranges in parts per million: arsenic, 2.3 to 10.7; beryllium, less than 0.1 to 0.2; mercury, 0.4 to 0.16; molybdenum, 2.0 to 30; antimony, 0.5 to 2.0; and selenium, less than 0.1 to 0.2. These values suggest that the Capps and Waterfall coal beds are comparable to other Alaskan and western U.S. coals of similar age, rank, and depositional environment.

Glaciology

Response of Blue Glacier To a Perturbation in Thickness and the Flow Law of Ice

KEITH ECHELMEYER (Division of Geology and Planetary Sciences, California Institute of Technology, Pasadena, Calif. 91125)
(Sponsor: Barclay Kamb)

The Blue Glacier, Olympic Mountains, Washington has undergone a substantial thickening and resulting increase in ice velocity. It thus provides a unique natural test for glacier flow theory: what is the response of a temperate, non-surging glacier to a geometrical perturbation? Information regarding flow law parameters in a power-law type constitutive relation for ice are obtained from a study of the resulting increase in velocity. In this paper observational data is compared with numerical models of glacier flow. The comparison enables an estimation of the flow law parameters for temperate ice and a determination of the important factors governing the flow of the glacier.

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of results obtained by these two sampling methods and statistically proved by correlation analysis.

CHANNEL GEOMETRY OF THE TANANA RIVER NEAR FAIRBANKS, ALASKA

Chacho, Edward F., Jr. (U.S. Army Cold Regions Research and Engineering Laboratory, Ft. Wainwright, AK 99703)

The Tanana River is a glacier-fed alluvial river with an average annual peak flow of 1700 m^3/s near Fairbanks, Alaska. The channel pattern of the river is braided upstream of the study reach and approaches a meandering channel through the study reach. Cross-sections have been surveyed on the river since 1977 in conjunction with the Corps of Engineers Chena Flood Control Project. The surveys show up to 10 m/year of lateral migration of the main channel. In some reaches of the river the channel cross-section has changed dramatically in both the vertical planes, aggradation or degradation, and the horizontal plane, channel shape and thalweg migration. The analysis presented shows the relationships between channel geometry and changes in the river course due to natural annual variations and influences due to construction activities in the river.

Hydrology of North Slope Coastal Plain Streams

BRENT T. DRAGE (Peratrovich & Nottingham, Inc., Anchorage, Alaska 99503)
JEFFREY F. GILMAN (Peratrovich & Nottingham)
DAVID HOCH (Peratrovich & Nottingham)
LESLIE GRIFFITHS (Peratrovich & Nottingham)

This paper presents the general hydrologic characteristics of the streams located on the coastal plain between the Kuparuk River and the Colville River on Alaska's North Slope. The data presented in this paper were gathered over the last five field seasons by the authors and others while working under contract with ARCO Alaska, Inc.

Following a general discussion of the geographic and climatic setting for these streams, there follows a discussion of several important hydrologic parameters which define the uniqueness of streams flowing in this environment. From discharge measurements, values for typical slopes, Manning's roughness factors, and Coriolis energy coefficients are presented.

Finally, a new flood frequency analysis for these streams has been developed using a Log Pearson Type III distribution in conjunction with a regional skew weighting analysis. The result of the analysis is a set of frequency curves for discharge per unit area vs. drainage area.

It is hoped that the data presented in this paper will serve as a baseline for future studies in North Slope hydrology.

Urban Air Pollution During Ice Fog Episodes

T. A. GOSINK (Geophysical Institute, University of Alaska, Fairbanks, AK 99701)
C. BENSON, S. A. BOWLING, C. FEIST, T. OHTAKE and G. SHAW (University of Alaska, Fairbanks).

Urban air pollution during winter at high latitudes can be significantly different in its physical and chemical properties as compared to the commonly studied warmer temperature counterparts. Chemical, physical and biological tests of air pollutants in Fairbanks, Alaska from the ice fog episode of December, 1980 are presented.

The air pollution products tend to be reduced, rather than oxidized. Nitric oxide predominates over nitrogen dioxide. Ozone is totally expended. Ammonia concentrations can be higher than the nitrate content in the fallout. Melted ice fog and snow is basic rather than acidic. There is some evidence for nitrosoamine production, and the melted ice fog is mutagenic.

On the Meteorological characteristics of polluted air masses at Barrow, Alaska

W. E. RAATZ (Geophysical Institute, University of Alaska, Fairbanks, Alaska 99701)
(Sponsor: Kolf Jayaweera)

...

along the edges. To acquire information pertinent to these problems major field, analysis and modeling programs are planned for the Bering and East Greenland Sea marginal ice zones.

Results from the MIZEX program will be directly applicable to many aspects of the Beaufort Sea summer ice edge region. Increased understanding of the complex interrelations between northern hemisphere ice edge location and large-scale meteorological parameters will enhance long-term predictability. The results of analysis and modeling efforts on ice edge related frontal structures will bear both upon studies of small-scale ice motions and biological productivity at and near the edge. New information on ice melting and freezing processes will aid in the prediction of small-scale ice edge behaviour and will enhance our understanding of oil-ice interaction. Finally, development of methods for modeling sea ice behaviour in the marginal ice zones will enhance both short-term predictive models and the ability to estimate hazards posed by the ice to structures.

Polynya Development and Floe Velocities in Response to Winds in the Eastern Bering Sea, March, 1976

LYN MCNUTT (F.G. Bercha and Associates Limited, 640 11th Avenue S.W., Calgary, Canada T2R 0E2)

Studies of satellite imagery show the locations of recurring winter polynyas in the eastern Bering Sea. They also provide information on floe velocities in these areas for the same times, and indicate a predominant north-northeasterly winter wind regime. Clouds obscure this region during periods of southerly wind flow and bias the data to cloud-free conditions. Occasionally, clouds remain in the southern portion of the imagery, exposing the northern polynyas for analysis. These conditions existed in March, 1976. Using the METLIB program, windspeeds superimposed on polynya and floe maps show the correlation of ice motion with the shifting wind and indicate the response time from the onset of the winds until the changes in the features occur. The floe motions seem correlate well with data from remote stations taken on the ice during similar conditions.

The Oceanography of the Bering Sea Ice Edge in Spring

H. J. NIEBAUER (Institute of Marine Science, University of Alaska, Fairbanks, Alaska 99701)
V. ALEXANDER (Institute of Marine Science, University of Alaska, Fairbanks, Alaska 99701)

Seasonal pack ice edge zones are air-ice-sea frontal systems that offer the opportunity to study the coupling of meteorological, and physical and biological oceanographic processes that are concentrated in time and space. In spring 1982 a cruise to the Bering ice edge zone was made to address questions on the role of physical processes in mediating spring phytoplankton blooms. Physical (T°C, S°/..) and biochemical (chlorophyl, NO_3, etc.) oceanographic data are presented addressing the role of spring ice melt in the spring bloom in this frontal system.

Tsunamis and Storm Surges in the Canadian Arctic and Implications for Offshore Work in the Beaufort Sea

T. S. MURTY (Institute of Ocean Sciences, P.O. Box 6000, Sidney, British Columbia, V8L 4B2)

Major earthquakes capable of generating tsunamis have occurred in the past at various locations in the Canadian Arctic, including the Beaufort Sea. Although not frequent, the tsunamis thus generated can present problems to coastal and offshore works. Even more serious than the tsunamis are the storm surges that occur quite regularly in the Canadian Arctic, and especially in the Beaufort Sea. For example, twenty-seven significant surges with amplitudes of one meter or greater have occurred during an eleven year period. The negative storm surges can create problems for navigation in the shallow regions of the southern part of the Beaufort Sea.

Ice appears to damp positive storm surges much more strongly than negative surges. Extensive ice cover in the shallow bays of the Southern Beaufort Sea can alter the periods of free oscillations so that the resonance amplification of surges could be quite different from winter to summer periods. Probability estimates made using various techniques show that, in the Southern Beaufort Sea, return periods of major surges are about three to five years. To study the development, propagation and amplification of storm surges, it is necessary to resolve the topography adequately and this can be achieved through the development of irregular triangular grid models.

Oceanographic Observations: West End Simpson Lagoon

T.J. Weingartner (Woodward-Clyde Consultants, Anchorage)
J.M. Colonell (Woodward-Clyde Consultants, Anchorage)

To provide a characterization of summer oceanographic conditions near Oliktok Point at the west end of Simpson Lagoon, hydrographic and current data were collected during the 1981 open-water season. Shallow depths (<3m) and small astronomical tide (<20 cm) in this area cause it to be primarily a wind-driven system, similar to other nearshore waters of the Beaufort Sea. The influence of the nearby Colville River (largest river on the Alaskan North Slope) is evident in major conclusions drawn from this study:

(1) Fresh water is advected into western Simpson Lagoon in substantial quantities during westerly wind events, with lowest salinities occurring northeast of Oliktok Point due to deflection of the plume by the point;

(2) Strong horizontal and vertical density gradients are established as a result of the confluence of marine and riverine waters in this area; serving to delimit clearly the boundaries of the fresh water plume under most wind conditions.

Results serve to underscore other observations of the dynamic and responsive character of the nearshore Beaufort Sea.

Oceanographic Impact of the Prudhoe Bay Causeway

J.M. Colonell (Woodward-Clyde Consultants, Anchorage)
P.A. Mangarella (Woodward-Clyde Consultants, San Francisco)
T.J. Weingartner (Woodward-Clyde Consultants, Anchorage)

Oceanographic data collected around the 4-km long gravel-fill causeway at Prudhoe Bay provide insight to the impact of such structures on the nearshore Beaufort Sea environment. Hydrographic (CTD) surveys and time series of currents, conductivity, and temperature were obtained in August-September 1981, a period referred to as the late open-water season.

Because of its shallow depths (<5m) and small astronomical tide (<20 cm), the nearshore Beaufort Sea is essentially a wind-driven system. Prevailing easterlies and storm-related westerlies are the wind regimes of interest. The northward orientation of the causeway, in combination with the generally east-west configuration of the coastline and barrier islands, cause development of dynamical features that correlate well with wind direction:

(1) On the windward side of the causeway an offshore-directed buoyant jet is caused by interruption of the longshore flow, and

(2) Upwelling occurs on the lee side of the causeway.

One consequence of these features is that salinities differ from one side of the causeway to the other by as much as 10 ppt. Other effects of the causeway include intensification of tidal currents in its vicinity and alteration of flushing times for the adjacent barrier island lagoon.

The Alaska Coastal Current

THOMAS C. ROYER (Institute of Marine Science University of Alaska, Fairbanks, Alaska 99701)

The narrow, intense, coastal current bordering the Gulf of Alaska is a phenomena that responds to many of the region's geological features and influences its oceanographic processes. The baroclinic portion of this current displays a seasonal response to the coastal runoff, but the current is also modified by the local winds. The runoff here is dependent not only on the precipitation rate but because approximately 20% of the drainage area is covered with glaciers, it is also dependent on air temperature and insolation.

There are many similarities between the Alaska Coastal Current and other high latitude currents, such as the Norwegian Coastal Current. However, it is unique in that the wind system over the Gulf of Alaska never reverses the coastal flow.

The coastal current is the major feature of the coastal circulation. It controls the nearshore and estuarine distributions of sediments, nutrients and marine organisms. Because coastal waters from the Gulf of Alaska enter the Bering and hence the Beaufort Sea, this coastal current acts as a source for these areas. It can also be considered as a major source of low salinity water for the North Pacific Ocean. The implication is that this coastal feature could affect the deep ocean circulation.

New research efforts are underway to define measure better the oceanographic properties of this flow. Hydrographic, current meter, meteorological, chemical and plankton studies are being planned.

A Case of Influx

GREGORY A. VAYDA (Institute of Marine Science, University of Alaska, Fairbanks, Alaska 99701)

The Alaska Coastal Current is a fiercely energetic narrow band of brackish water which flows westward along the northern Gulf of Alaska bordering the rocky southern coast of Alaska. Its source inputs are the high rate of freshwater runoff from the coast and the insidious longshore easterly wind. The freshwater influx causes a cross shelf density gradient which drives a longshore baroclinic current. The shoreward Ekman transport, which results from the longshore wind, tends to accrete the brackish water into a narrow band and thus maintains the integrity of the flow.

Until recently the extent of the collusion between the longshore transport and the wind was unknown. This paper presents an energy balance to ascertain the relative contribution of wind and freshwater to the longshore transport.

Deep Water Circulation in a Sub-arctic Fjord: Smeaton Bay, Alaska

DAVID L. NEBERT (Institute of Marine Science, University of Alaska, Fairbanks, Alaska 99701)

Current meter and hydrographic data are used to describe the circulation in Smeaton Bay, a silled fjord in southeastern Alaska. The region has relatively high precipitation rates and large tides. A dominant feature is a net outflow near sill depth during much of the year. Net outflows at the sill have been observed during times of high local discharge and during bottom water renewal. Another dominant feature is the inflow at 15 to 30 m. This inflow is generally considered to be a salt continuity flow necessary to replenish salt lost through seaward transport of the surface brackish layer.

Speculations as to the causes of the sill-depth outflow are presented and related to the ... circulation.

TWO APPROACHES TO WAVE HINDCASTING

David P. Krauel (Royal Roads Military College, FMO, Victoria, B.C., V0S 1B0)

The results of two approaches to hindcasting wind waves in limited fetch coastal areas are presented and compared. Both methods use adjusted observed wind records which are representative of the wave generating area. For most coastal engineering applications, a knowledge of the frequency distributions of wave heights and periods is required. The two approaches employed to reach these end products are:

(1) determine the frequency distributions of waves hindcasted on an hourly basis from hourly wind speeds and directions observed over a ten year period, and

(2) hindcast the frequency distribution of waves from the frequency distributions of wind speed and direction over the same ten year period. The latter method is much simpler but assumes that the wind waves are fetch limited and not dependent upon the wind duration.

The two results of the wave hindcasts for two coastal locations are compared in detail: Comox, Vancouver Island where fetches are less than 50 km in the Strait of Georgia and southwestern Newfoundland where fetches are up to 350 km in the Gulf of St. Lawrence.

Benthic Eddy Diffusivities and Gas Exchange Rate Estimates using RADON

DAVID M. GLOVER (Institute of Marine Science University of Alaska Fairbanks, Alaska 99701)
WILLIAM S. REEBURGH

The distribution of radon-222 and radium-226 was investigated in the PROBES project area of the southeastern Bering Sea. A large and fairly uniform radon-222 flux from the sediment leads to a small or nonexistent radon deficiency at the sea surface in the shallow regions. Integrated radon-222 deficiencies have been used to calculate stagnant film thicknesses and gas exchange rates, so this high bottom radon flux complicates calculation of gas exchange rates here. Tidal mixing near the bottom is so intense that it requires two-dimensional modeling to explain the benthic eddy diffusivity data. Radium-226 in the area has two distinct signatures with the off shelf waters being approximately a factor of 2-3 higher than the on shelf waters. We have exploited this difference in shelf break fine structure studies. A cross shelf section of radium-226 has maximums and minimums suggesting influence by biological activity.

Partial Pressure of Carbon Dioxide from pH and Salinity

T. A. GOSINK (Geophysical Institute, University of Alaska, Fairbanks, AK 99701)
J. J. KELLEY (Institute of Marine Science, University of Alaska, Fairbanks, AK 99701)

The partial pressure of carbon dioxide in sea water can be rapidly and accurately (± 6 ppm) determined from a corrected in-situ pH and the salinity (± 0.2°/..) as shown in equations (1) and (2)

$$PCO_2 = a\, pH_C^n \qquad (1)$$

$$pH_C = pH + (pH \times sal/1000) \qquad (2)$$

There will be a discussion of the sea water carbon dioxide-carbonate system from a slightly different perspective. Comparison of PCO_2 as determined from classical calculation, direct observation and this new method will be presented. The new method has been successfully employed since its discovery in 1979 for deep as well as surface water samples. On the N.B.S. reference pH scale the values for "a" and "n" (equation 1) are 3.98 x 10^{20} and -19.568 respectively.

Seismology

Seismic Gaps along the Queen Charlotte Fault

G. C. ROGERS (Pacific Geoscience Centre, Earth Physics Branch, P.O. Box 6000, Sidney, B.C. Canada V8L 4B2)

Relocation of earthquakes that have occurred along the Queen Charlotte Fault since 1900 indicates that two seismic gaps may currently exist. One which has previously been identified, lies to the north of the Queen Charlotte Islands, between the north end of the aftershock zone of the 1949 Queen Charlotte Islands earthquake (M = 8.1) and the 1972 Sitka earthquakes (M = 7.6). It may be up to 150 km in length. The other gap is located between the south end of the 1949 aftershock zone and the 1970 Cape St. James earthquake (M = 7). This is a region about 75 km in length, which has not experienced a major earthquake since at least the turn of the century. Since 1950, it can be confirmed that the region has also been devoid of moderate shocks. Earthquakes with magnitudes of about 7-3/4 and 7-1/2 respectively, would be required to completely fill these two gaps.

Tree-Ring Evidence for Uplift at Icy Cape, Alaska, Related to 1899 Earthquakes in the Yakataga Seismic Gap

G.C. JACOBY and L.D. ULAN (Tree-Ring Laboratory, Lamont-Doherty Geological Observatory of Columbia University, Palisades, N.Y. 10964)

This study and others show that tree-ring analysis can provide information about past major earthquake events. If occurrence and recurrence of large, pre-historic events can be determined by tree-ring analysis, this information will be an important addition to the paleoseismological record.

Great earthquakes occurred in September 1899 on the southeastern coast of Alaska near Icy Cape (west shore of Icy Bay), an area now included within the Yakataga seismic gap. Due to glacial coverage of the present bay area in 1899 and to the scarcity of observers, tectonic deformation at Icy Cape related to these earthquakes went unrecorded.

Tree-ring analysis shows improved radial-growth rates after 1900 for trees at two locations on the seaward margin of a hypothesized pre-1899 wave-beaten shoreline. The oldest trees found on the surface between these trees and the present shoreline started growing in 1902. In addition, principal component analysis of the tree-ring data from 1880 through 1920 indicates that the trees at the terrace margin show a common low-frequency growth trend that differs from inland trees. The tree-ring evidence and the geomorphology can be explained by local uplift at Icy Cape and/or by rapid influx of sediments from avalanched headwater areas and meltwater from retreating glaciers.

Seismic Activity in the Vicinity of Anchorage, Alaska, 1972-82

J. C. LAHR, C. D. STEPHENS (U.S. Geological Survey, Menlo Park, CA 94025)

We have reviewed earthquakes located within 100 km of Anchorage during 1972-82, utilizing

the St. Elias earthquake has been remarkably similar to that observed prior to 1979. In a zone extending about 80 km inland from the coast between Prince William Sound and Yakutat Bay the seismicity is characterized by broad concentrations of shallow (35 km depth) activity separated by regions of relative quiescence. Within this zone the epicenters define 5-10 km patches within the aftershock zone of the St. Elias earthquake, a diffuse pattern around Waxell Ridge near the center of the gap, and a cluster of epicenters near the mouth of the Copper River Delta. North of the coastal zone a WNW.- to ESE.-trend of shallow activity punctuated by small clusters of epicenters extends along the south flanks of the Wrangell Lavas to the southeast end of the Totschunda fault system. Concentrations of epicenters also occur offshore near the western end of the gap. A NW-to-SE trend of activity extending along the northeast margin of the Yakutat foreland may confirm the presence of a previously inferred fault. The St. Elias aftershock zone is one of the few areas being monitored where focal depths are sufficiently reliable to resolve dipping structures; in this area the hypocenters define a shallow, diffuse zone that dips about 10° N. and probably corresponds to the low-angle thrust between the Pacific and North American plates.

Earthquake Relocation by the JHD Method in the Kodiak Island and Lower Cook Inlet Areas of Alaska

H. PULPAN (Geophysical Institute, University of Alaska, Fairbanks, Alaska 99701)
C. FROHLICH (Institute for Geophysics, University of Texas, Austin, Texas 78712)

An adaptation for local network data of the Joint Hypocenter Determination (JHD) method was used to simultaneously relocate 243 selected earthquakes which were very well recorded by a regional seismic network in the Kodiak Island-Alaska Peninsula and Lower Cook Inlet areas. In Cook Inlet, the relocated events clearly define a 10- to 20-km thick Benioff zone dipping at an angle of about 45 degrees. Several well-located events lie distinctly beneath the main zone by about 15 to 20 km. These results agree well with those reported by Lahr (1975) for this area. In the Kodiak Island-Alaska Peninsula area, the Benioff zone dips at about 40 degrees and there is approximately a 10-degree difference in the strike direction of the Benioff zone between the two areas. Thirty-five aftershocks of the 1964 Alaska earthquake located on the Kodiak shelf area were also relocated with the JHD method, using teleseismic data. The relocated epicenters lie along the shelf break in a much less diffuse cluster than the epicenters reported by the ISC. The depths of six of the events were redetermined using depth phases. These events define a narrow, gently dipping shallow thrust zone.

Progress Report on the Earthquake Prediction Effort at Elk Lake, Washington

WENDY C. GRANT
CRAIG S. WEAVER (both U.S. Geological Survey, at Geophysics Program, AK-50, Univ. of Wash., Seattle, WA 98195)
DAVID FRANK (U. S. Geological Survey, at Geological Sciences, AJ-20 Univ. of Wash., Seattle, WA 98195)
JAMES E. ZOLLWEG (Geophysics Program, AK-50, Univ. of Wash., Seattle, WA 98195)

The magnitude 5.5 (M_L) earthquake that occurred on February 14, 1981 near Elk Lake, Wash., was the largest earthquake to occur in Washington since the Seattle (M_L =6.5) earthquake of 1965. Moreover, the Elk Lake earthquake is the largest moderate shallow-crustal earthquake in western Washington in recent history.

Aftershocks were still occurring from the February 1981 main shock ...

The Petrology, Geochemistry and Isotope Geochronology of the Gilmore Dome and Pedro Dome Plutons Fairbanks District, Alaska

J. D. Blum (Mohawk Resources Alaska, Inc., P.O. Box 74224, Fairbanks, Alaska 99707) (Sponsor: S. E. Swanson)

Igneous Petrology and Geochemistry of Northern Akutan Island, Alaska

J. D. ROMICK (Alaska Division of Geological and Geophysical Surveys, College, AK 99708; Geology/Geophysics Program, University of Alaska, Fairbanks, AK 99701) (Sponsor: S. E. Swanson)

Volcanology

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Aeronomy

Geochemistry

... earth and air mass conditions. When high cation (and anion) data are deleted, low pH correlates well with high nitrate. Sulfate concentrations are similar to those measured in 1936 and do not correlate with pH. Calcium and, to a lesser extent, ammonium tend to increase pH values. High nitrate values also correlate positively with high excess acidity, while high sodium and calcium values correlate with high excess alkalinity. (Acid rain, acid precipitation, pH, geochemistry).
Water Resour. Res., Paper 3W0041

1410 Chemistry of the atmosphere
THE GLOBAL DISTRIBUTION OF ATMOSPHERIC CARBON DIOXIDE. II. A REVIEW OF PROVISIONAL BACKGROUND OBSERVATIONS, 1978-1980.
P.J. Fraser (CSIRO Division of Atmospheric Physics, Aspendale, Victoria 3195), G.I. Pearman and P. Hyson.

An attempt is made to bring together provisional data collected throughout the world to construct a global picture of the background atmospheric carbon dioxide concentration distribution. The uncertainties, calibration and sampling difficulties, and measurement needs are discussed and it is concluded that in general the accuracy of the provisional data at each sampling location is ~±1 ppmv. On-going studies at the main laboratories are likely to significantly improve this accuracy in the near future.

The most recent data available (for 1980) indicates annual average northern hemisphere high latitude CO_2 concentrations 4 to 5 ppmv above those at high latitudes of the southern hemisphere (~336 ppmv). The greatest uncertainty in the zonal average concentration exists in the latitude band 10-30°N where surface observations are 2-3 ppmv higher than those measured by continuous analysis at the Mauna Loa Observatory. There is generally good agreement between a model-generated and the observed annual mean global distributions.

The seasonality of concentration is small in the southern hemisphere (~1-2 ppmv peak to peak) rising to ~6 ppmv at 20°N and ~15 ppmv at high latitudes of the northern hemisphere.

The total global atmospheric CO_2 content, averaged through 1980, is estimated to have been 7.15×10^{14} kg of carbon with a probable uncertainty of 0.5 to 1.0%. (Carbon dioxide, atmospheric monitoring).
J. Geophys. Res., Green, Paper 3C0115

1410 Chemistry of the Atmosphere
A DECONVOLUTION OF THE TREE RING BASED $\delta^{13}C$ RECORD
T.-H. Peng (Oak Ridge National Lab., Oak Ridge, Tennessee, 37830), W. S. Broecker, H. D. Freyer, and S. Trumbore

A composite record of $^{13}C/^{12}C$ for the last 150 years has been constructed for the cellulose from open site trees. Using an Oeschger-type ocean model this record has been deconvolved to yield the anthropogenic CO_2 input over this time period. The known fossil fuel inputs have been subtracted from this input yielding an estimate for the forest and soil component. This analysis yields a total input via forest and soils somewhat greater than that via fossil fuels. However during the last 20 year time period for which an atmospheric CO_2 record is available the fossil fuel input has been about five times greater than the forest-soil input. The forest-soil input appears to have peaked close to the turn of the century and has been declining toward the present. Because of this decline the change in atmospheric CO_2 content over the last 20 years attributable to forest and soil inputs has been quite small. However because of the remaining questions about the validity of the ^{13}C record derived from the studies of tree rings our analysis has to be taken more as an example of the power of the ^{13}C approach than as a firm estimate of the magnitude of the forest-soil contribution to the CO_2 rise.
J. Geophys. Res., Green, Paper 3C0129

Geodesy and Gravity

Electromagnetics

Geomagnetism and Paleomagnetism

Exploration Geophysics

Hydrology

3110 Erosion and Sedimentation
BAR RESISTANCE IN GRAVEL-BED STREAMS AT BANKFULL STAGE
K. L. Prestegaard (Department of Geology, Franklin and Marshall College, Box 3003, Lancaster PA 17604)

3110 Erosion and sedimentation
LAND USE, FLOODS, AND CHANNEL CHANGES: UPPER MIDDLE FORK WILLAMETTE RIVER, OREGON (1936-80)
Joseph K. Lyons (Utah Division of Oil, Gas and Mining, 4241 State Office Building, Salt Lake City, Utah 84114), Robert L. Beschta

3130 Groundwater
OPTIMIZATION OF GROUNDWATER ABSTRACTION FROM A COASTAL AQUIFER
E.H. Morel (Burmah Oil Exploration Ltd, Pipers Way, Swindon, Wiltshire SN3 1RE, UK) and A.B. Birtles

An analytical mathematical model, based on Jacobian elliptic functions, has been used to identify feasible wellfield locations and pumping rates for large-scale abstraction from an unconfined coastal aquifer. The choice of optimum feasible wellfield strategy has been made using a simple economic model which calculates the cost ...

... Mass balance calculations using the verified chemical models predict a spatial distribution of calcite cementation that closely matches the observed distribution in the Aquia aquifer. This suggests that the observed calcite cementation is post-depositional in origin and has resulted from reaction of ground water with aquifer material.
Water Resour. Res., Paper 2W1990

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Volume 18, Number 2

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Atmospheric and Oceanic Physics
Volume 18, Number 3

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3130 Groundwater
AQUIFER PARAMETER IDENTIFICATION WITH KRIGING AND OPTIMUM PARAMETERIZATION
W. W-G. Yeh (School of Engineering and Applied Science, University of California, Los Angeles, California, 90024), Y.S. Yoon (Hoyle Engineering Corporation, San Diego, California 92111) and K.S. Lee (School of Engineering and Applied Science, University of California, Los Angeles, California, 90024).

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Meteorology

[illegible]

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Volume 19, Number 4

6545 Interior of planets
REPLY TO THE CRITIQUE OF REASENBERG & BILLS ON 'ELASTIC THICKNESS OF THE VENUS LITHOSPHERE'
A. Cazenave and K. Dominh (Groupe de Recherche de Géodésie Spatiale, Centre National d'Etudes Spatiales, 18, Avenue Edouard Belin, 31055 Toulouse Cedex, France)
In a previous study (Cazenave and Dominh, 1981) ...

These structures have been explained as due to global expansion and contraction, basin subsidence, or both. Even if the extension implied by all lunar grabens are due to global expansion, the total radius increase permissible would be much less than that predicted ...

Particles and Fields—Magnetosphere

Physical Properties of Rocks

Planetology

Seismology

Social Sciences

Solar Physics, Astrophysics, and Astronomy

Tectonophysics

... discontinuous, relatively rapid (compared to spreading rate) and that re-alignment of ridge segments near the propagator tip is an important component.
J. Geophys. Res., Red, Paper 2B1805

8150 Plate tectonics
INVESTIGATIONS OF A VINE-MATTHEWS MAGNETIC LINEATION FROM A SUBMERSIBLE: THE SOURCE AND CHARACTER OF MARINE MAGNETIC ANOMALIES
K. C. Macdonald, (Department of Geological Sciences and Marine Science Institute, University of California, Santa Barbara, California, 93106), S. P. Miller, B. P. Luyendyk, T. M. Atwater and L. Shure
We report here the first attempt to directly map the boundary of a Vine-Matthews magnetic stripe on the sea floor. Our objectives are to study the processes of oceanic crustal accretion as recorded in the reversal transition zone and to investigate the formation of ...
... suggest that circa 0.7 my ago the crustal accretion zone (magnetized volcanic, intrusive and plutonic rocks) was 2000-2800 m wide, while the zone of recent volcanism alone was only 1000-2000 m wide. This determination for the most recent reversal agrees well with submersible observations at the present spreading center where the zone of recent volcanism (neovolcanic zone) varies between 600 and 2000 m in width. (magnetic anomalies, Pacific, ALVIN, geomagnetism)
J. Geophys. Res., Red, Paper 2B2003

Volcanology

Physics of the Solid Earth
Volume 18, Number 1

SCIENTIFIC COMMUNICATIONS

Physics of the Solid Earth
Volume 18, Number 2

SCIENTIFIC COMMUNICATIONS